

# *Introduction to the Physical Oceanography of the Baltic Sea Environment*

Baltic Way Summer School, Sept.18,  
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S Y K E



# Content

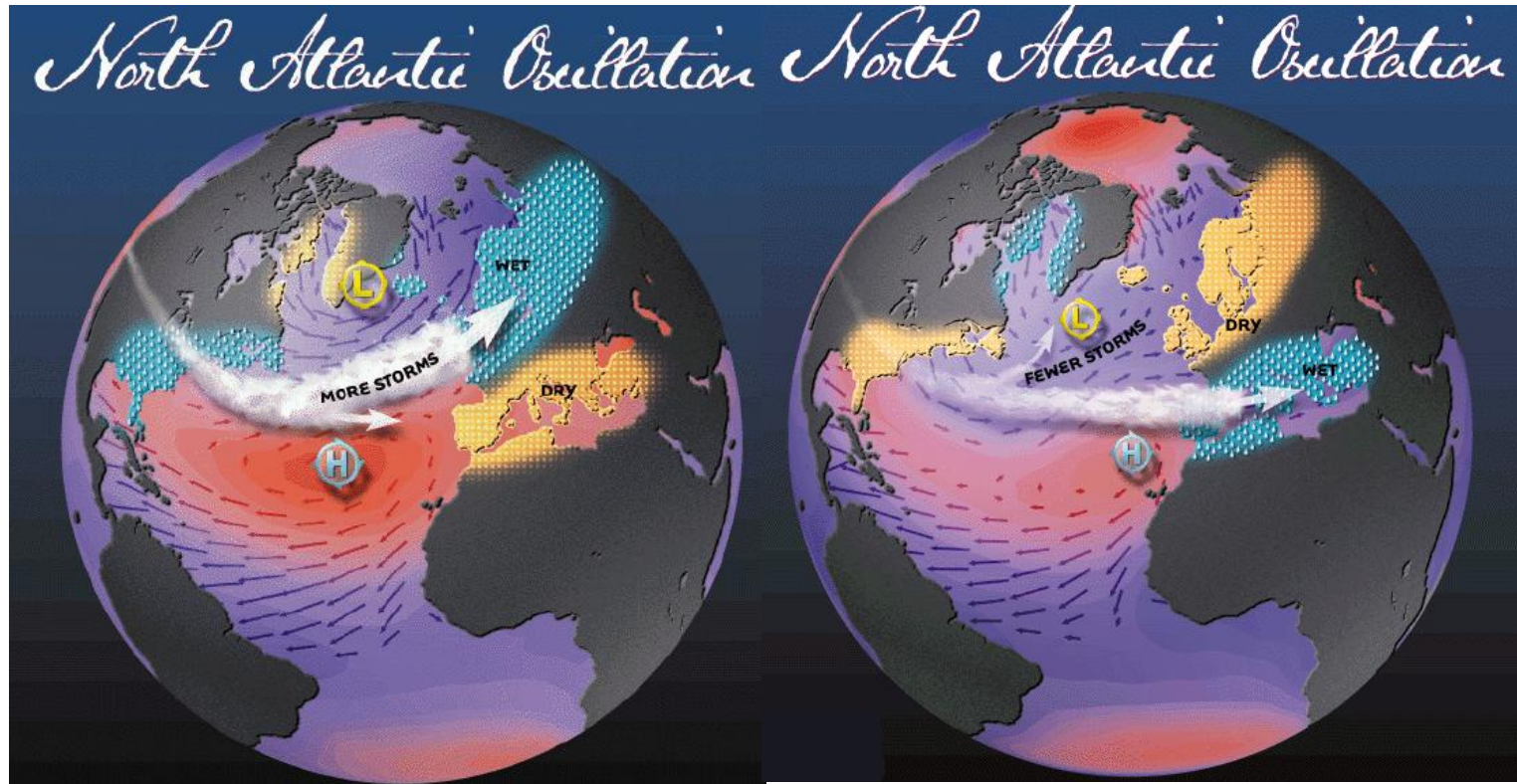
- 1. Basic physical features**
  - 2. Climate Change**
  - 3. Environmental problems –the state of the sea**
- Future of the Baltic Sea?**



# Physics



The Baltic Sea climate and water exchange with the North Sea is governed by Global Climate and its variability - North Atlantic climate is described by NAO-index (**North Atlantic Oscillation**)



NAO+ high westerly winds, mild winters, lot of precipitation

NAO- dry, cold winters, northerly wind



# Baltic Basin

Mean depth 54m.

(Oceans 3500 m.)

Åland Deep 301m.

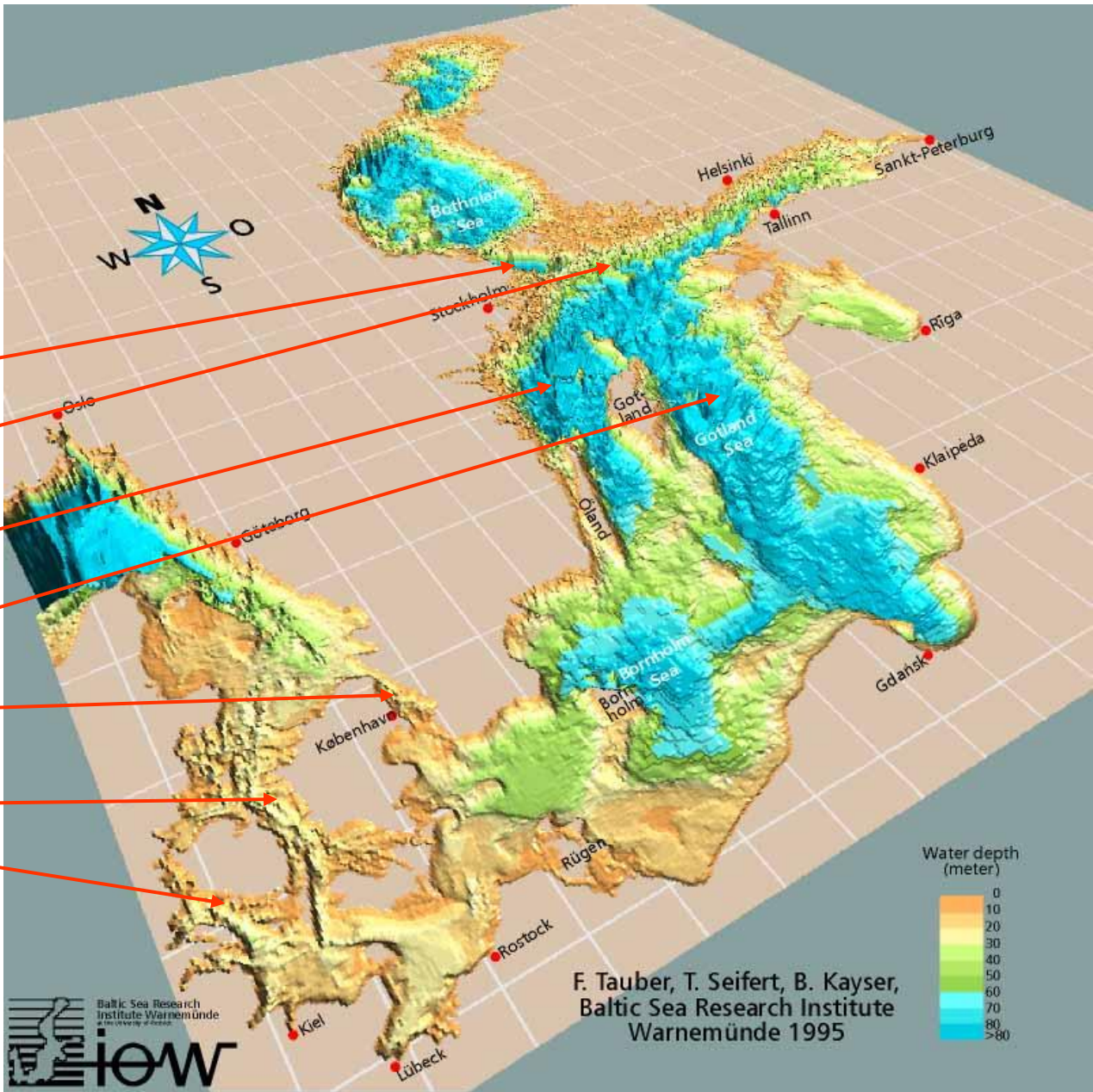
Salpausselkä Sill!

Landsort Deep 459m, BS max depth

Gotland Deep 239m.

Straits: Öresund and

Belts



**Baltic Basin IOW**



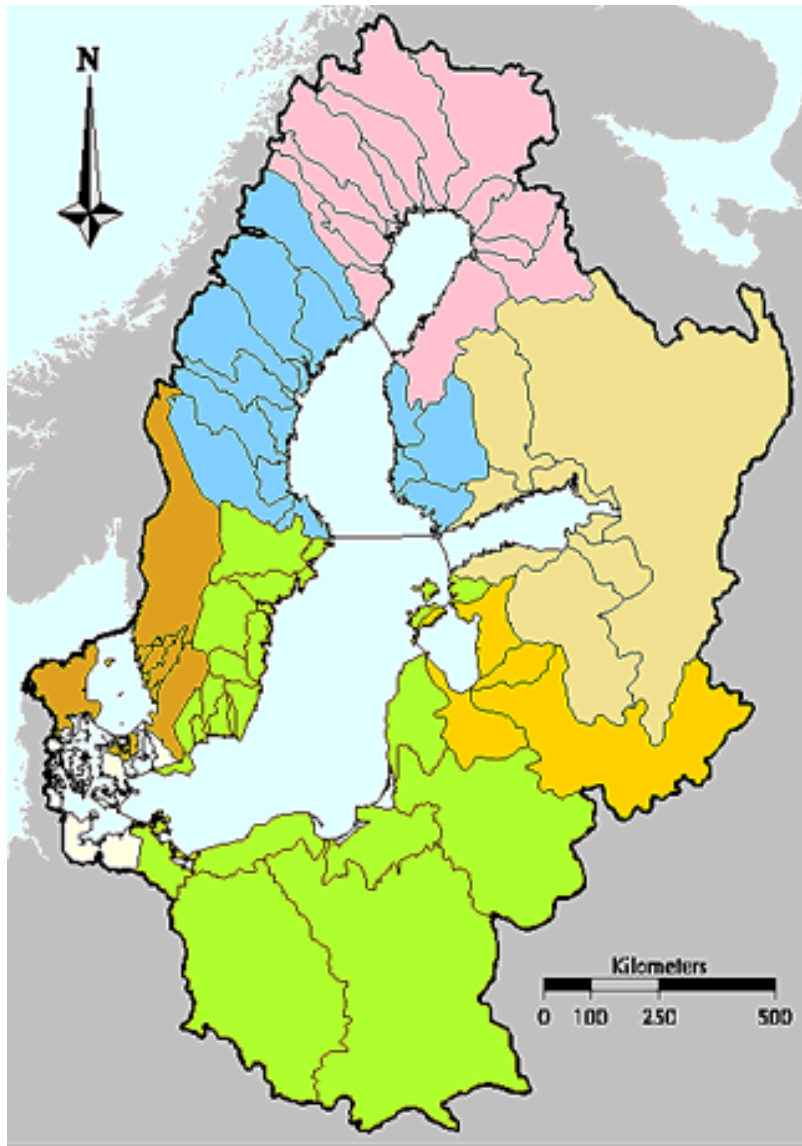
F. Tauber, T. Seifert, B. Kayser,  
Baltic Sea Research Institute  
Warnemünde 1995

# Baltic Sea basins



# Baltic Sea basins





## Drainage Basin

- Much larger than the area of the BS

- 1 721 233 km<sup>2</sup>

A=392.978 km<sup>2</sup>

V=21.205 km<sup>2</sup>

- 85 milj. People

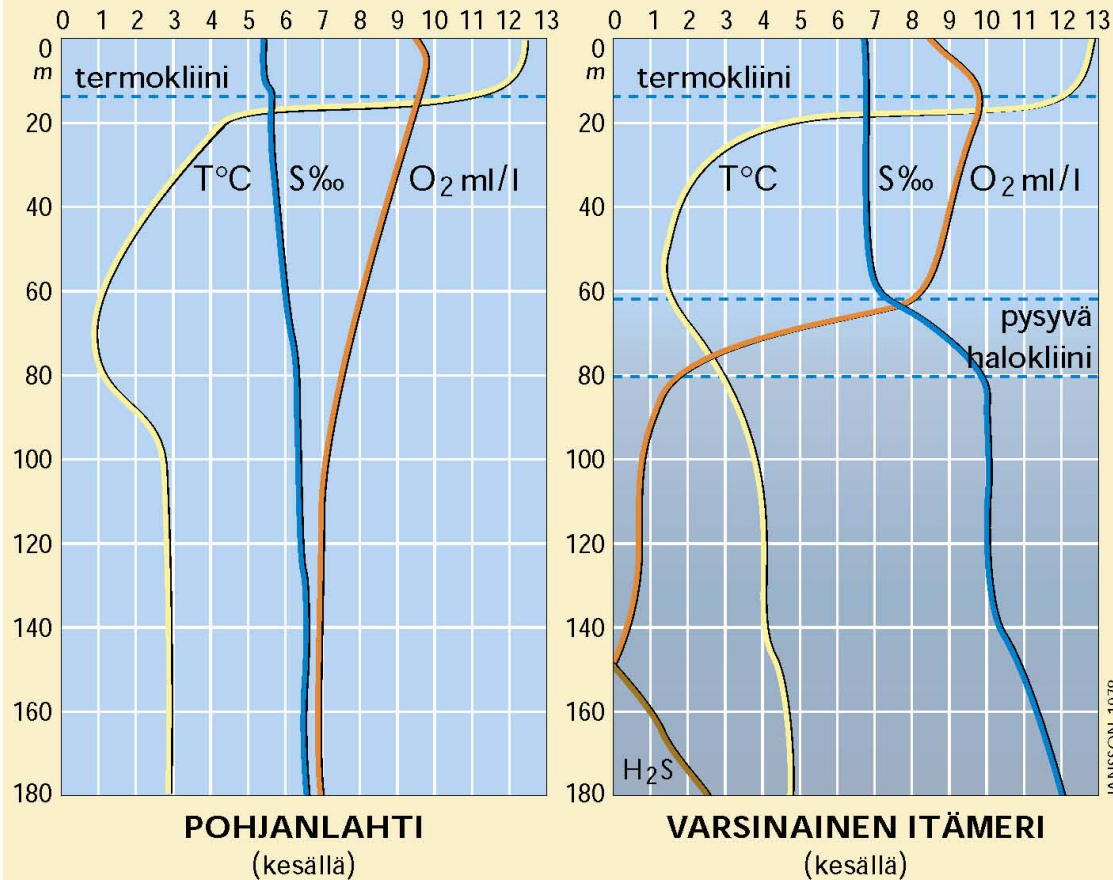
- 14 Countries (9 coastal)

- Lot of industry, agriculture, cities....



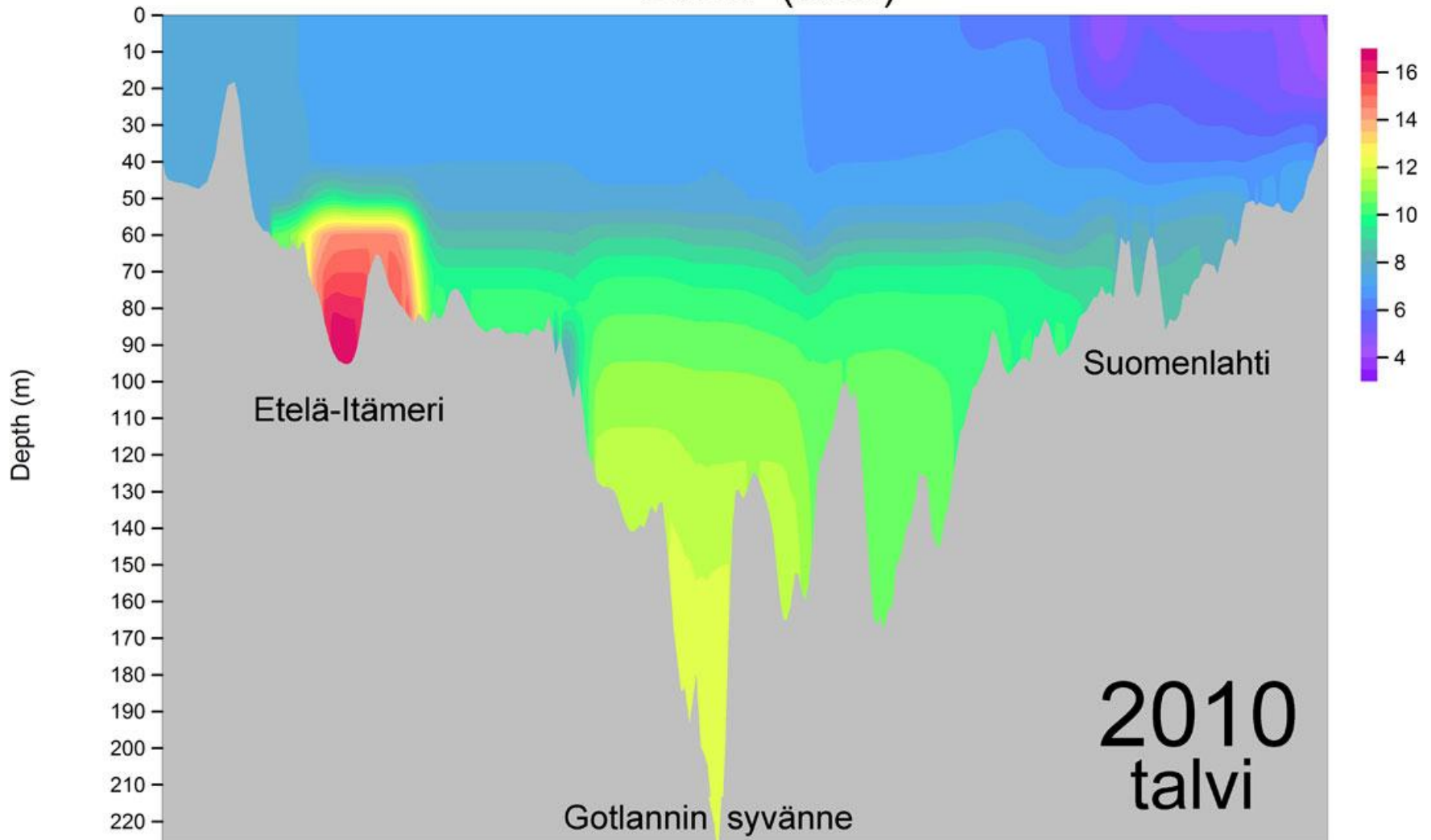
Baltic Sea temperature (yellow), salinity (blue), oxygen (red). Left: Bothnian Sea, Right: Gotland Deep (Furman et al.)

**ITÄMEREN HYDROGRAFIA;  
VESIPATSAAN POIKKILEIKKAUS**



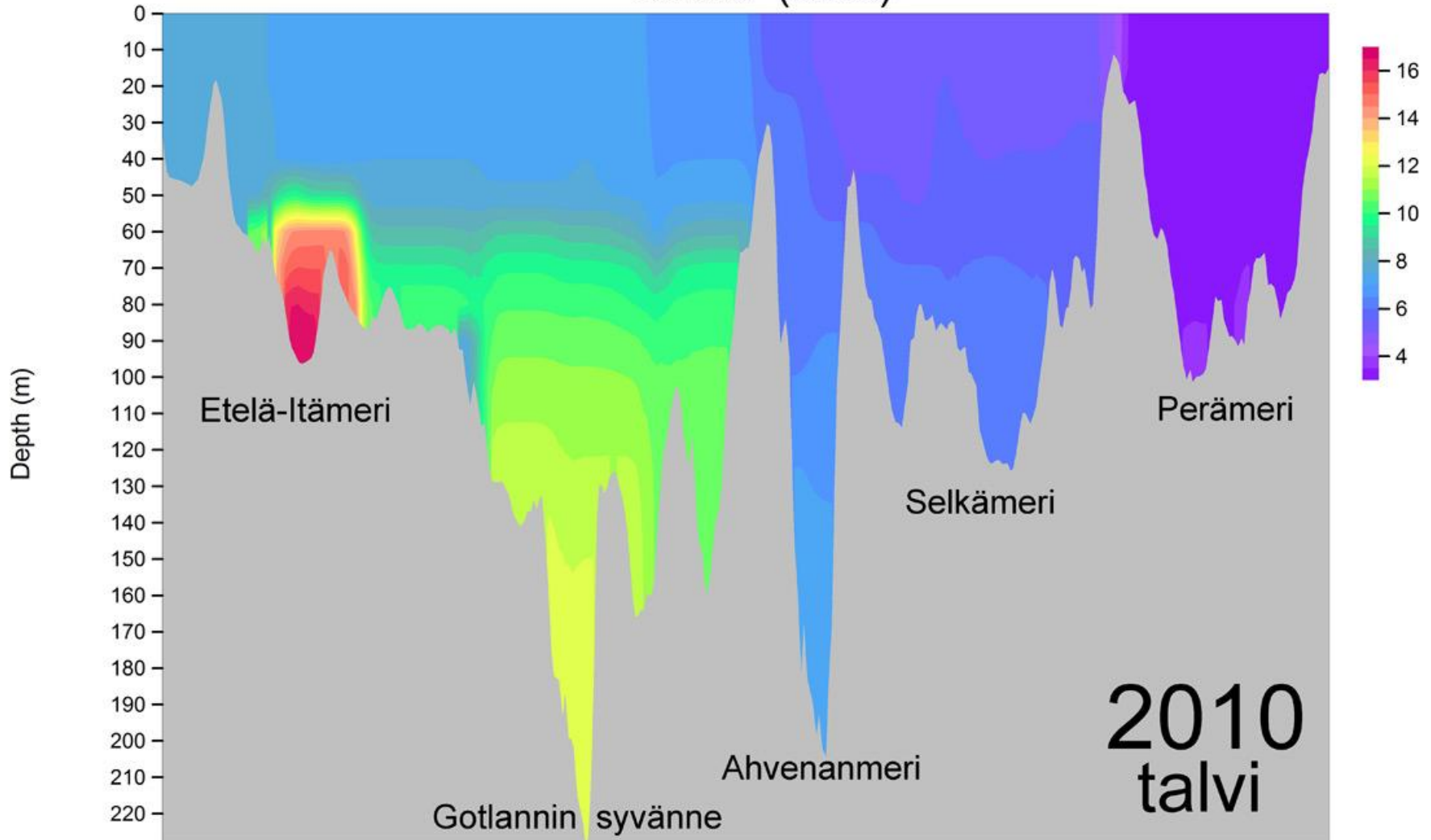
# Salinity cross-section: Southern Baltic-Gotland Deep-Gulf of Finland (winter 2010)

Suola (o/oo)

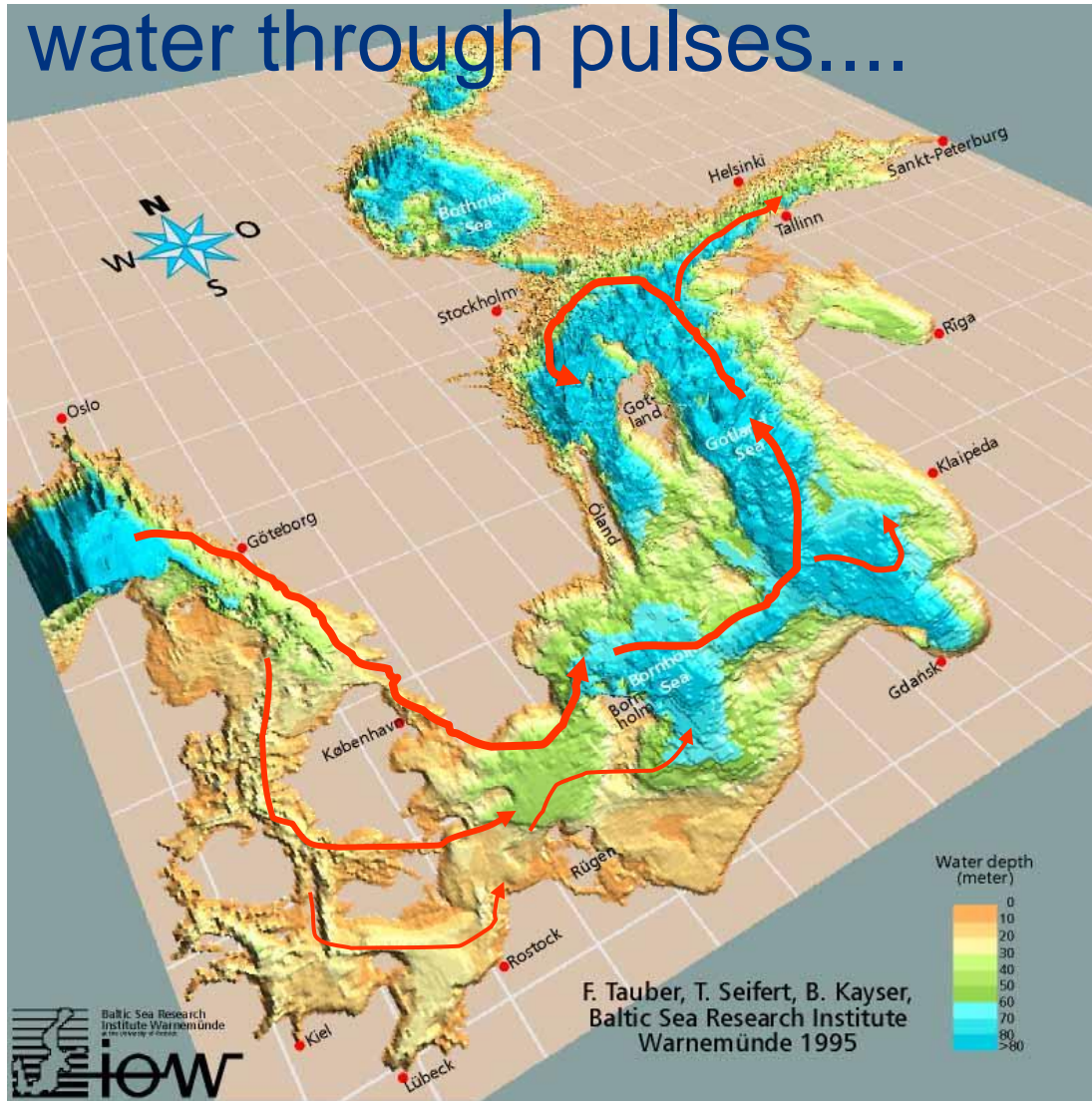


# Salinity cross-section: Southern Baltic-Gotland Deep-Gulf of Bothnia (winter 2010)

Suola (o/oo)

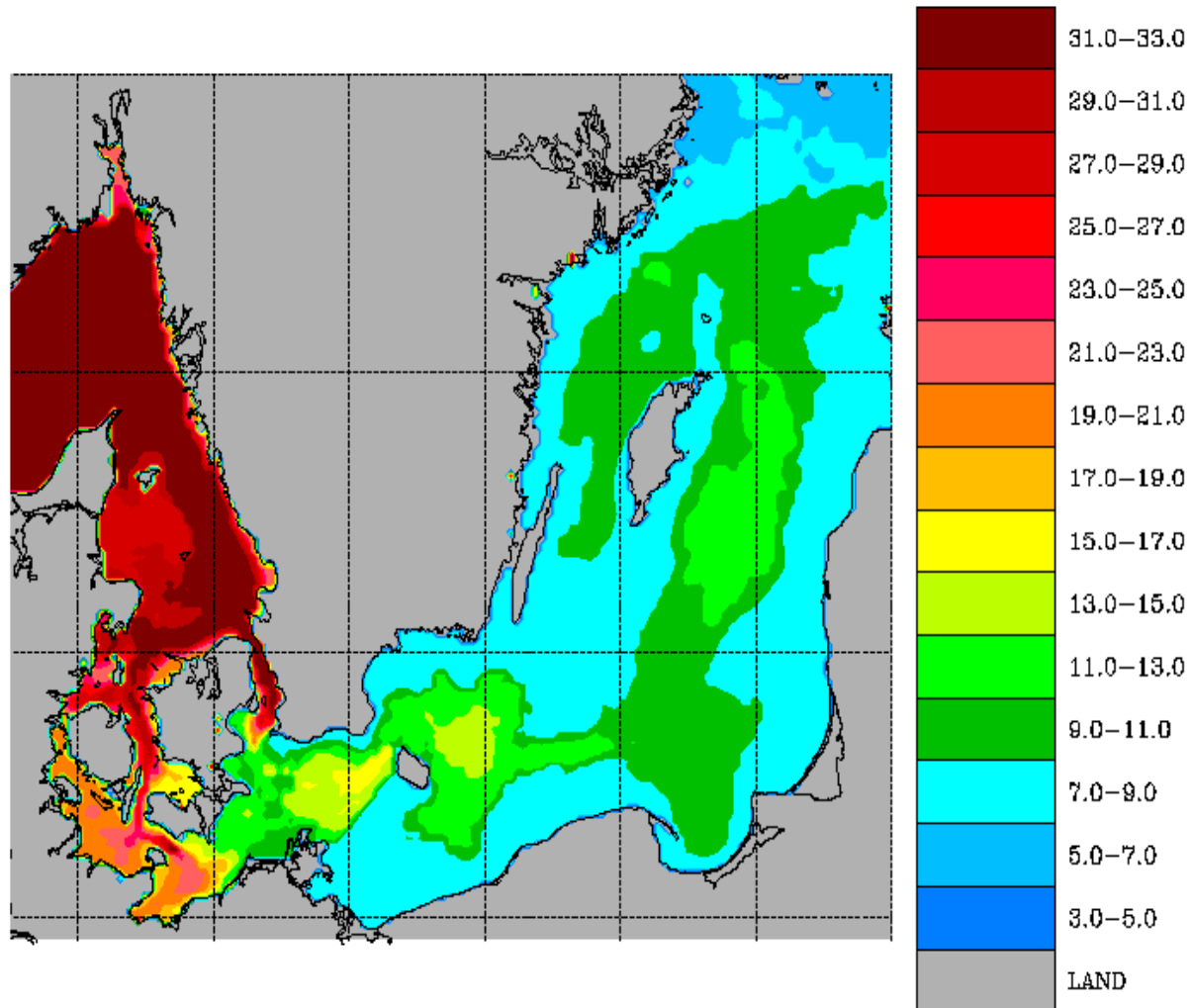


# Saline and oxygen-rich water through pulses....





# •1993 Major Baltic inflow (A. Lehmann)



# Energy balance

- $Q_n = Q_s - Q_r + Q_{La} - Q_{Lo} + Q_c + Q_e + Q_p,$

where  $Q_n$  is net heat flux.

The sum

$$Q_R = Q_s - Q_r + Q_{La} - Q_{Lo} \text{ is}$$

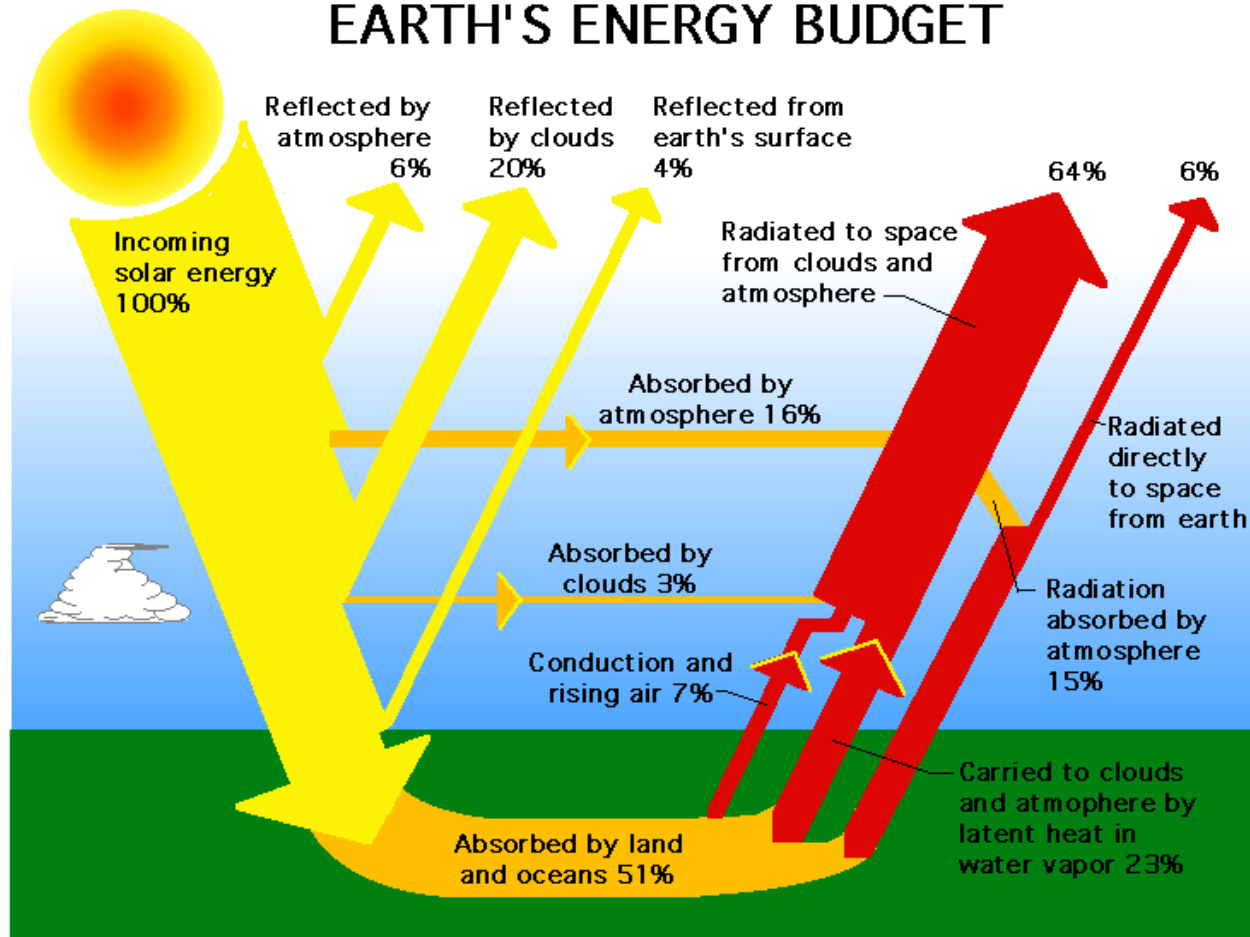
The radiation balance at sea-surface

$$Q_c + Q_e \text{ is}$$

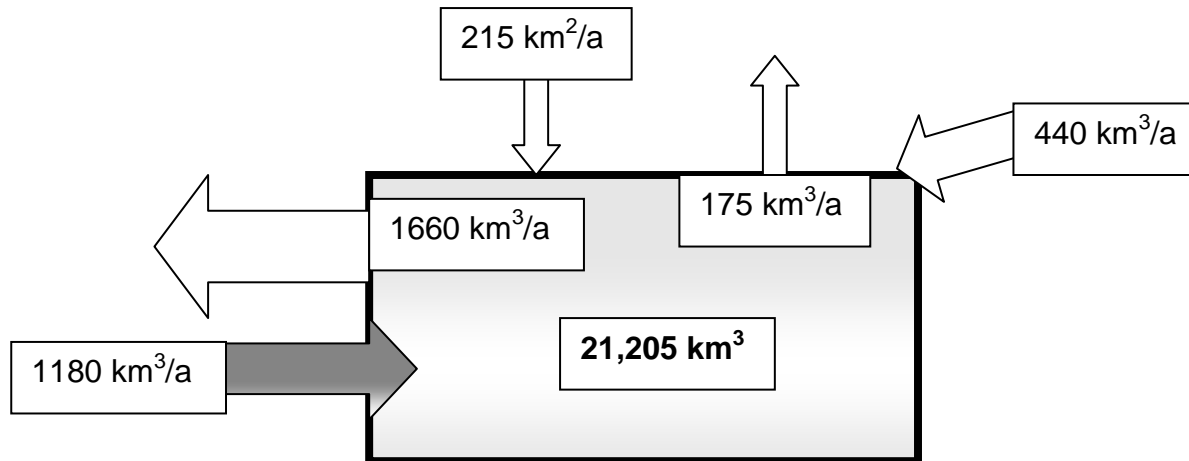
Turbulent heat

# Energy balance

## EARTH'S ENERGY BUDGET



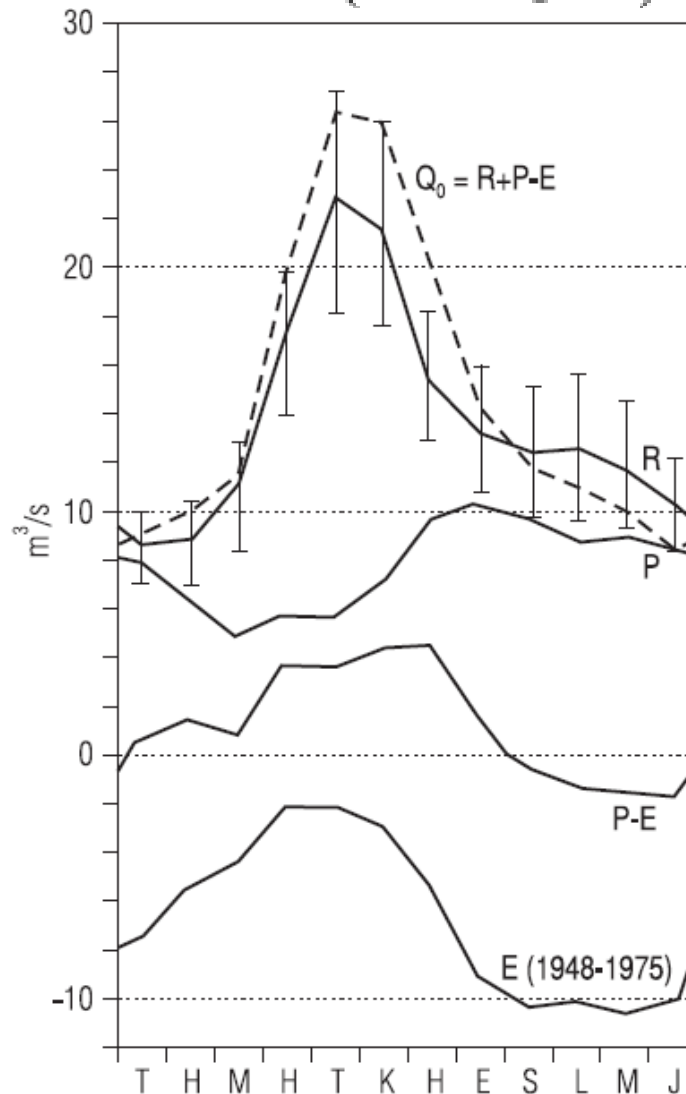
# Baltic Sea water balance





# Fresh water balance

*Makean veden tase* (kuva 5.8) on  $F = (P - E)A + V_r$ .



# Water balance

- Precipitation P 50 % of River runoff (445 km<sup>3</sup>/y)
- Annual inflow to BS from Kattegat 1.200 km<sup>3</sup> (1000-1.500 km<sup>3</sup>)
  - ← about 3 times R which equals to 3.2 m thick water layer at the BS surface
- monthly water storage max-min 500km<sup>3</sup> (1.25m, like R)

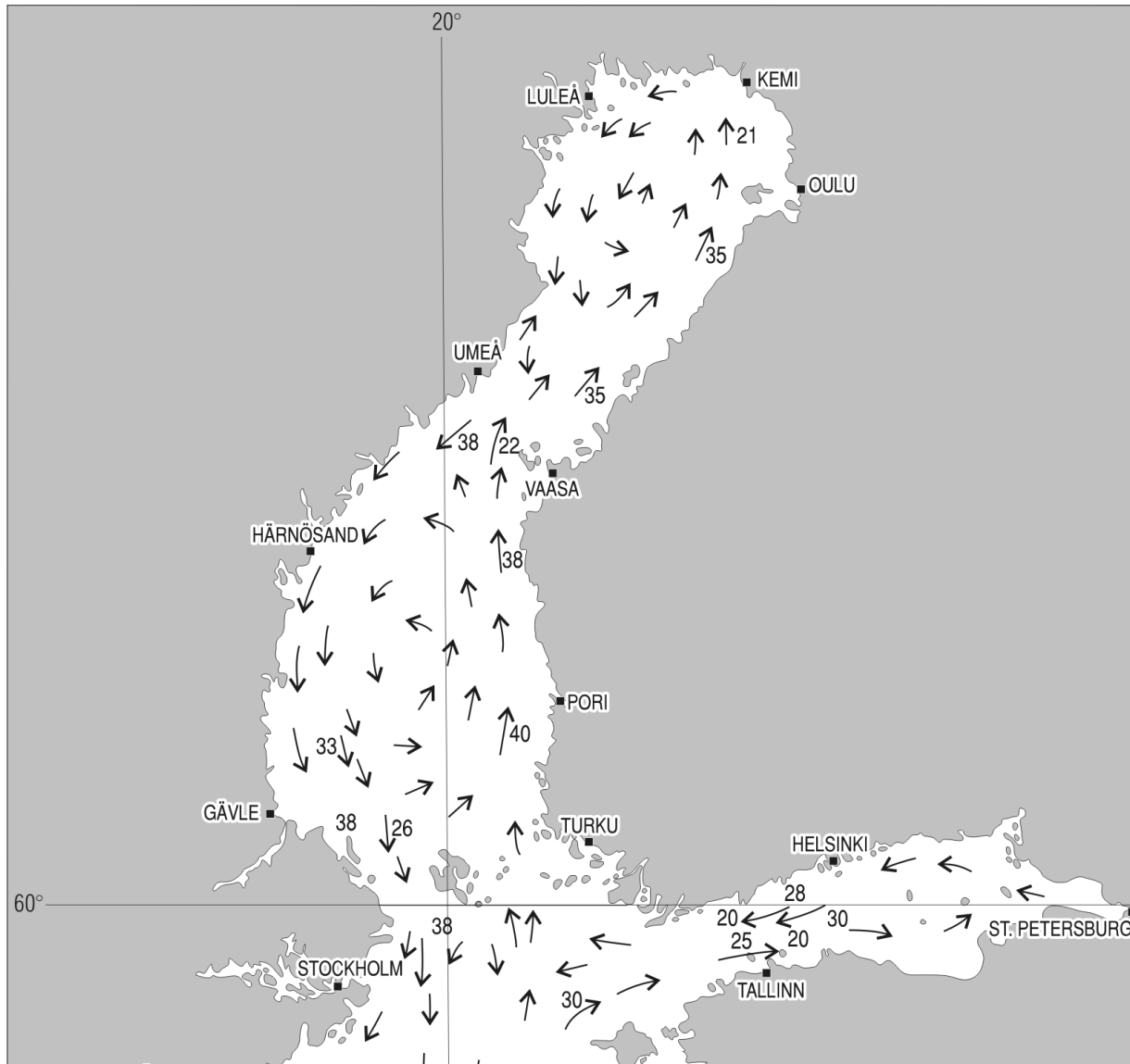
# Main equations

$$\frac{\partial \mathbf{u}}{\partial t} + (\mathbf{u} \cdot \nabla) \mathbf{u} + w \frac{\partial \mathbf{u}}{\partial z} + \mathbf{f} \times \mathbf{u} = - \left( \frac{1}{\rho_0} \right) \nabla p + D_u + f_w \quad (2.1)$$

$$\frac{\partial S}{\partial t} + (\mathbf{u} \cdot \nabla) S + w \frac{\partial S}{\partial z} = D_s + f_s \quad (2.2)$$

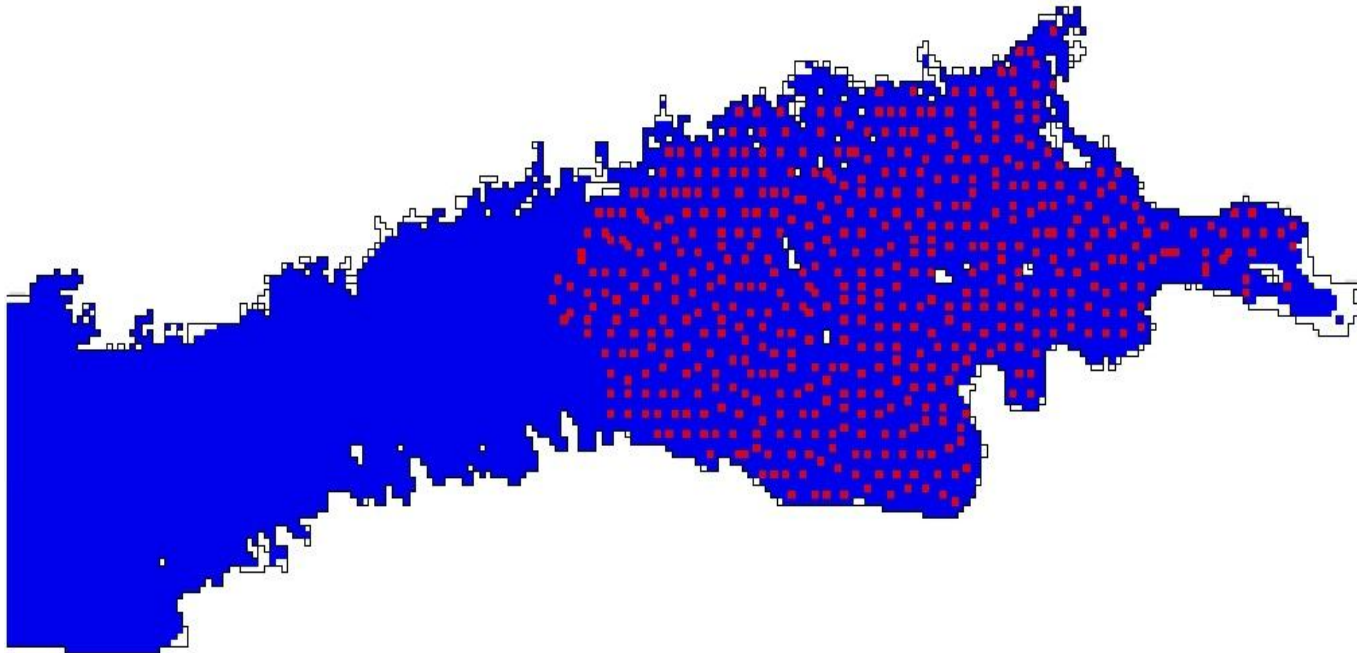
$$\frac{\partial T}{\partial t} + (\mathbf{u} \cdot \nabla) T + w \frac{\partial T}{\partial z} = D_T + f_T \quad (2.3)$$

# Baltic Sea mean surface circulation

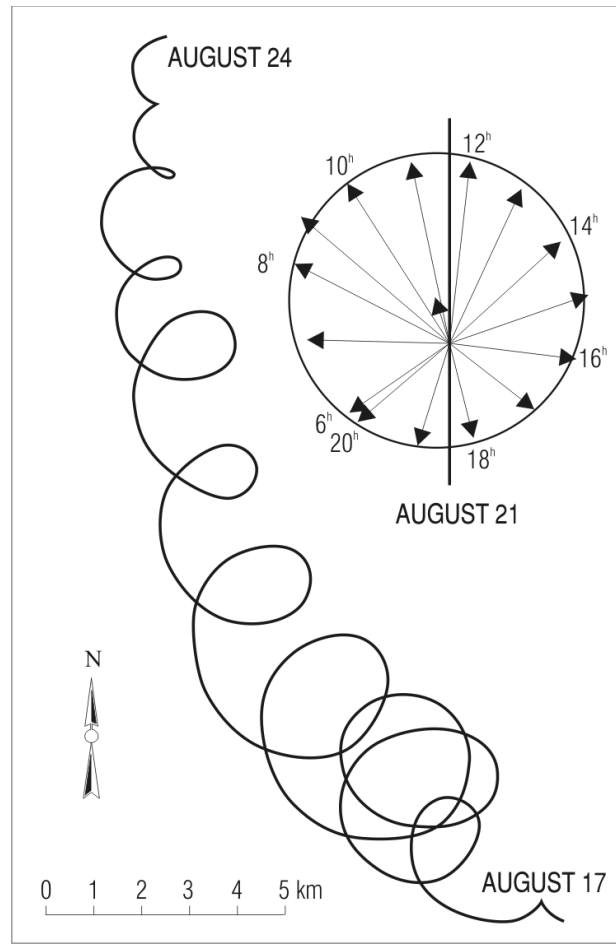




Mean current  
animation.  
Depth 5m.

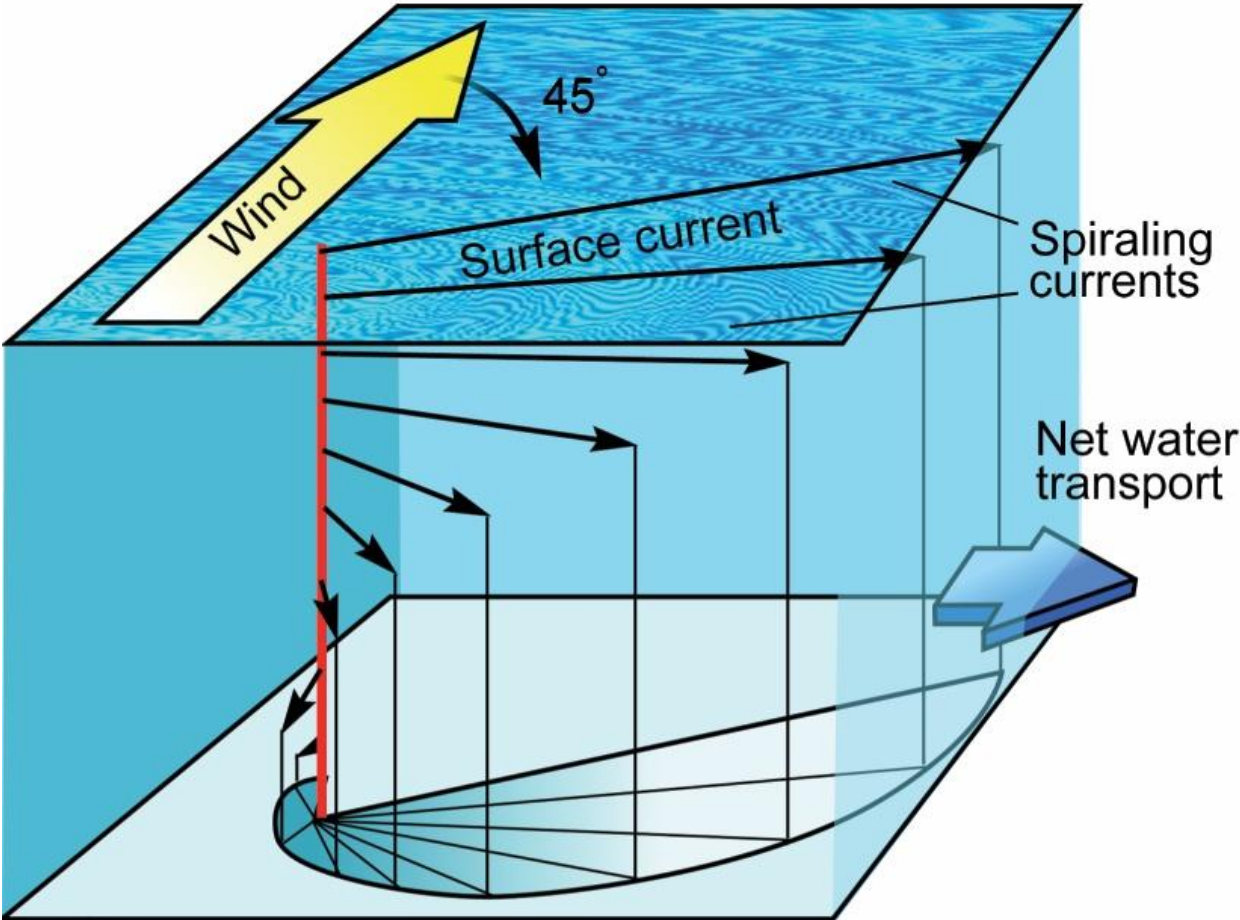


# Inertial oscillations

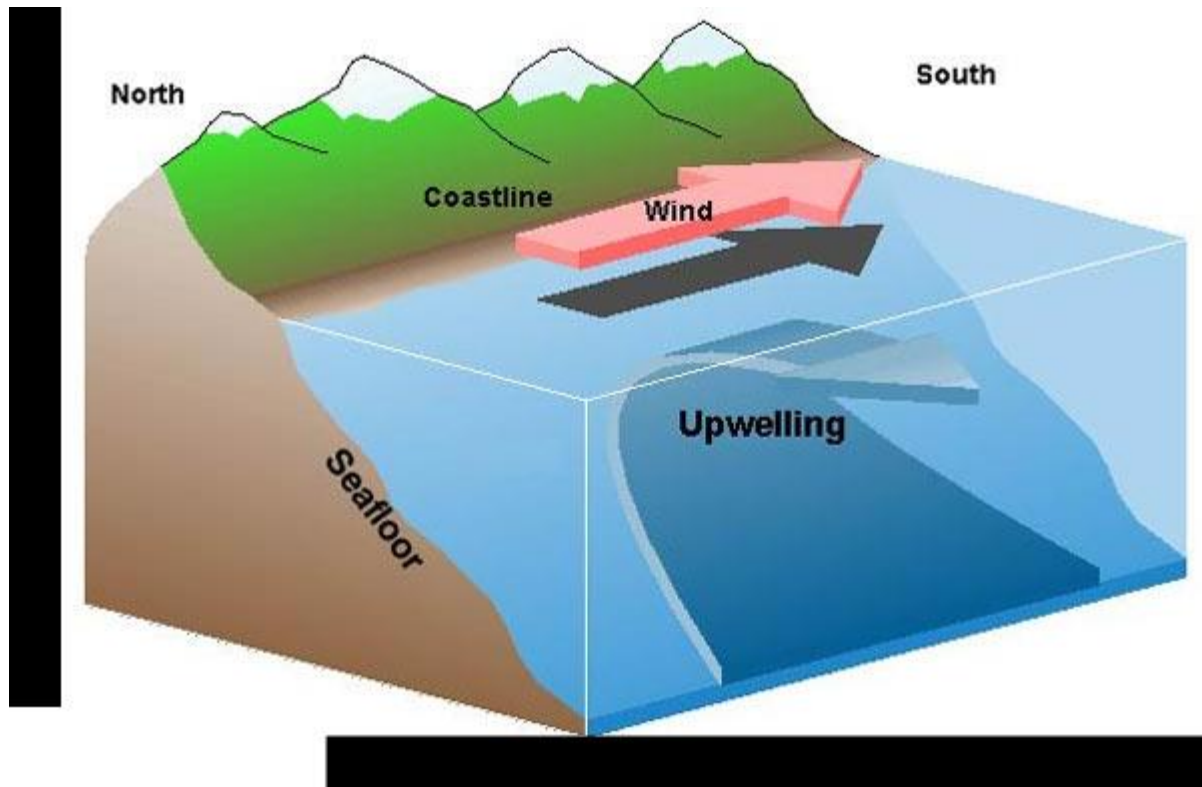


# Water circulation

Ekman-spiral:



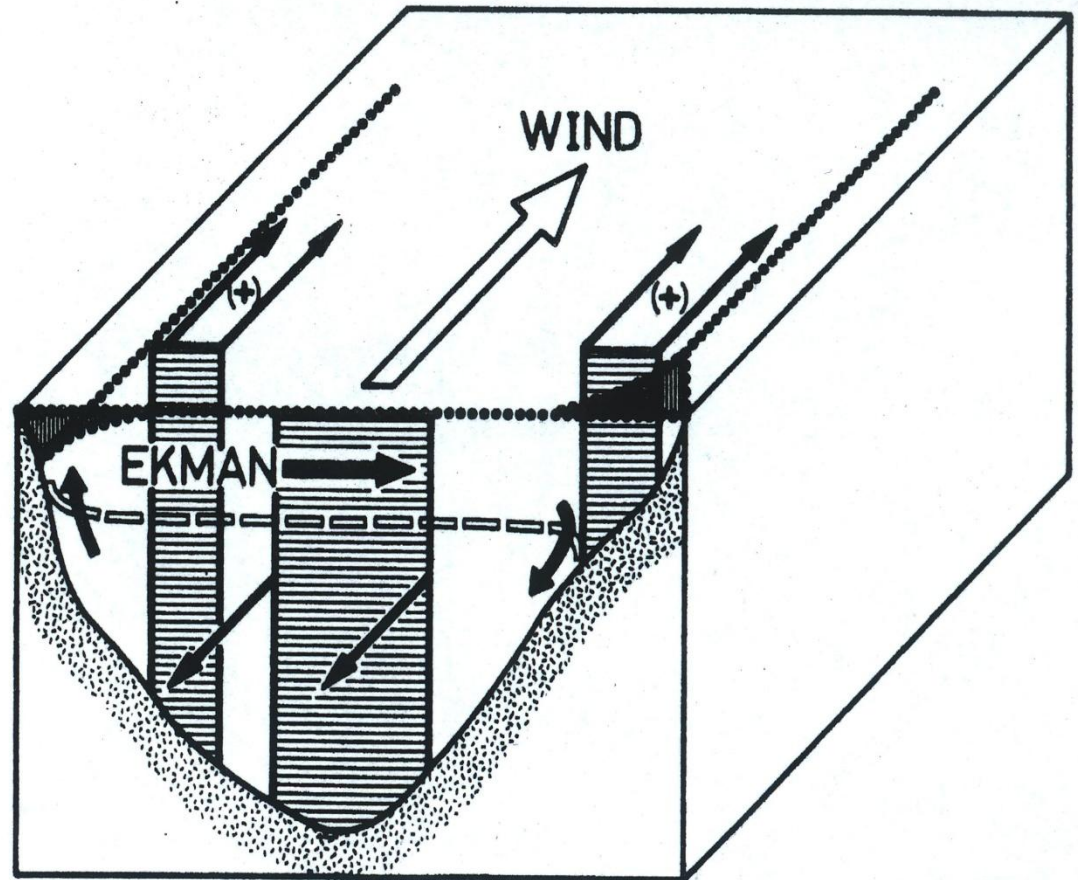
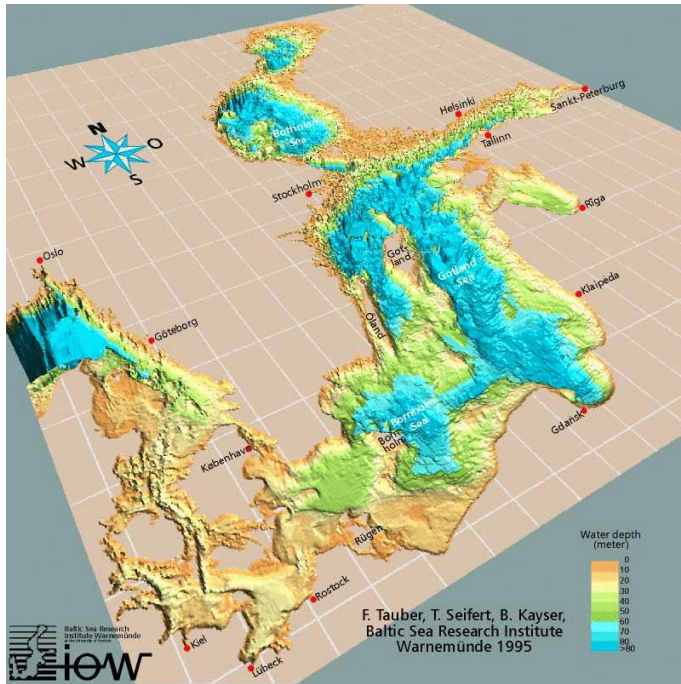
# Upwelling





# Upwelling in the Baltic Sea

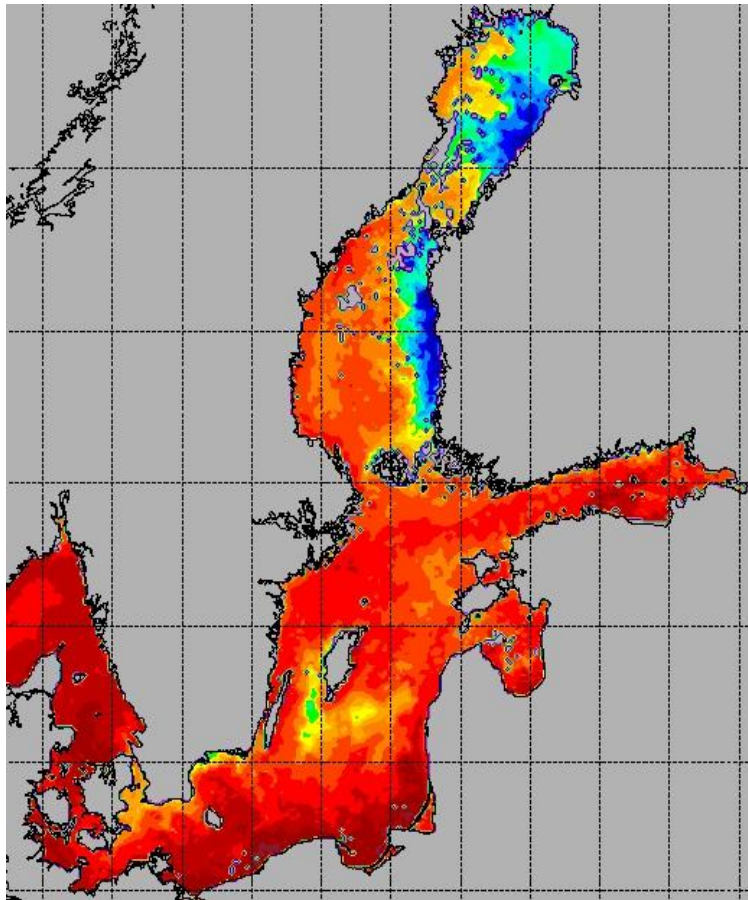
- Upwelling principles



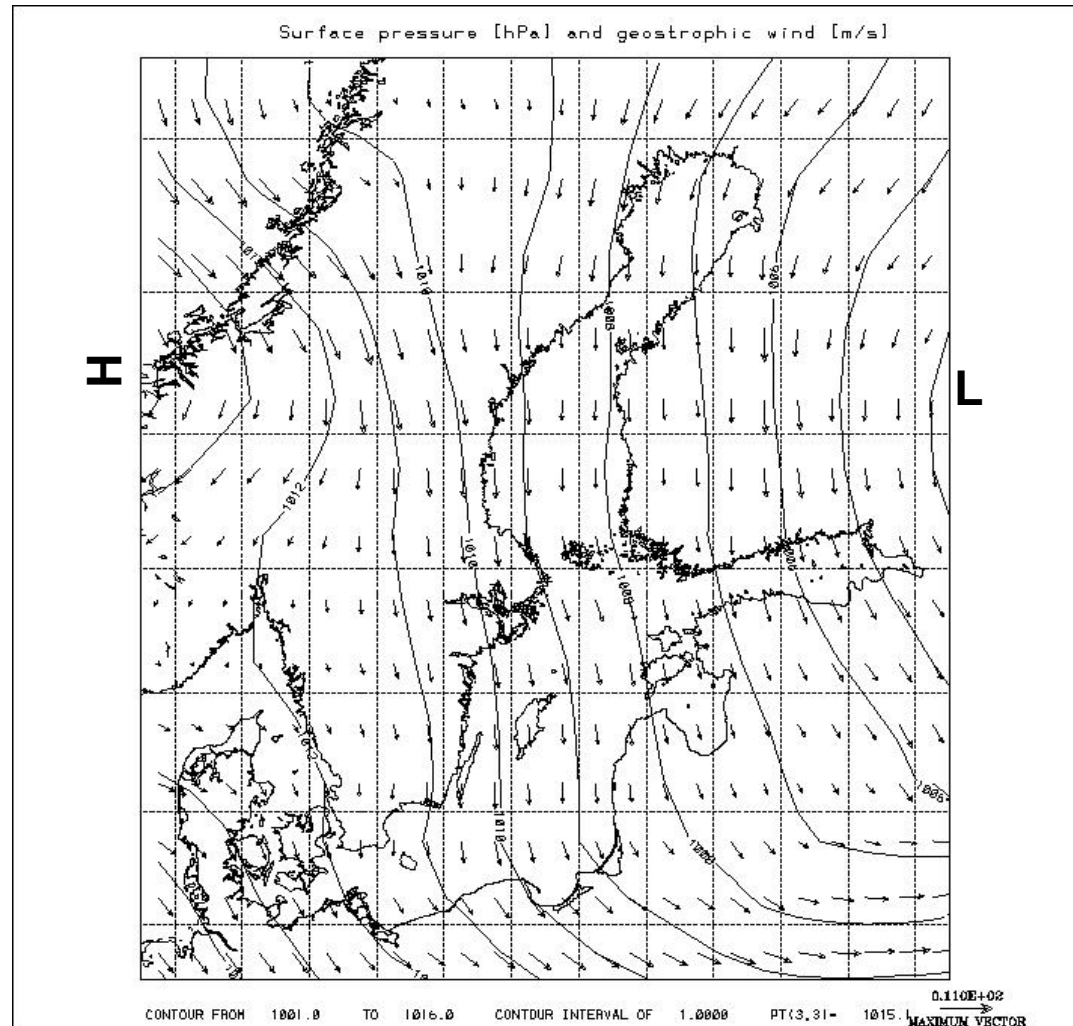
# Upwelling in the Baltic Sea

- Upwelling in relation to wind

27.08.-02.09.2003

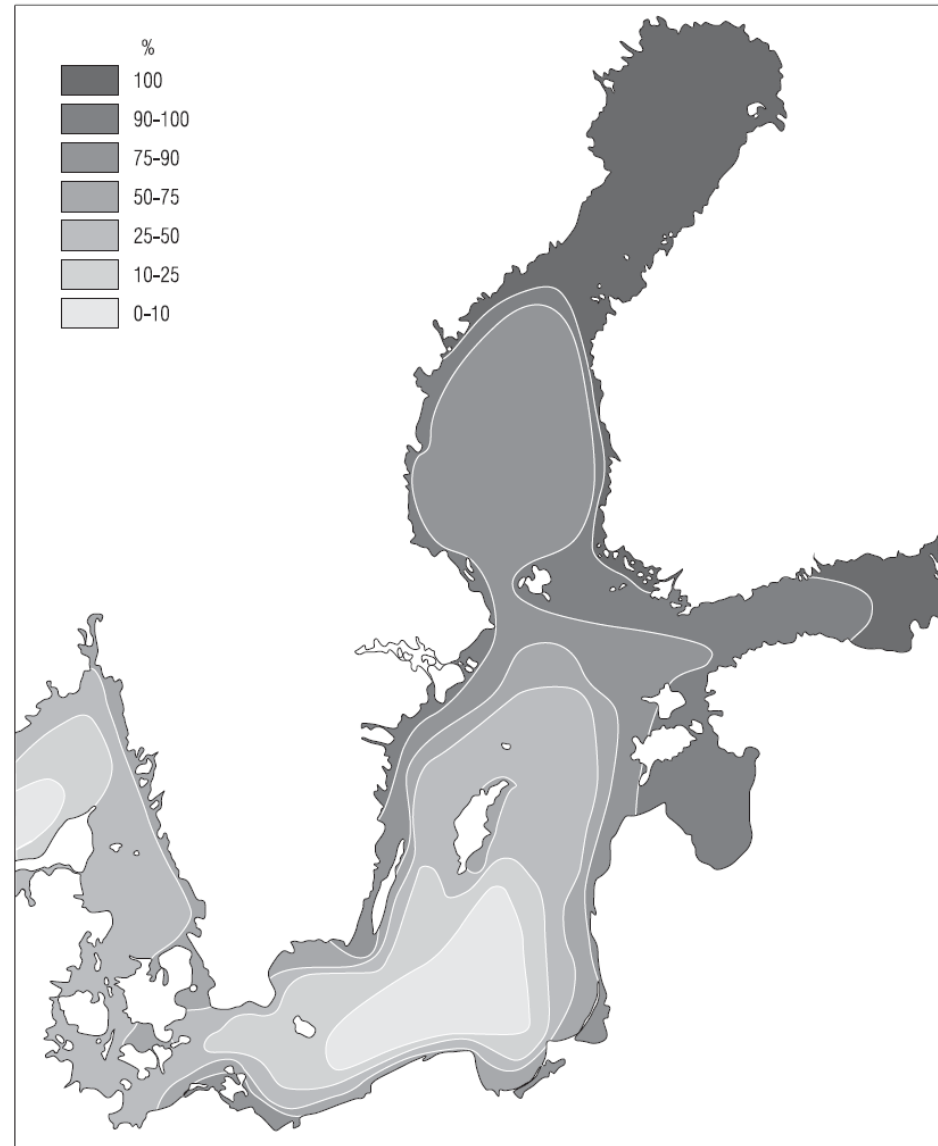


NOAA-AVHRR  
SST °C



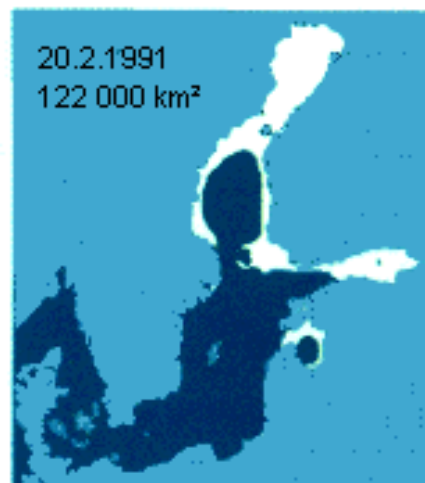
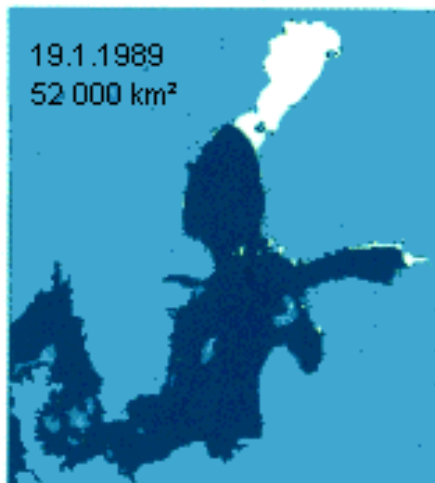
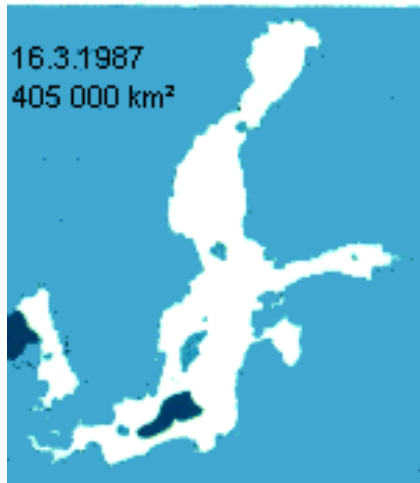
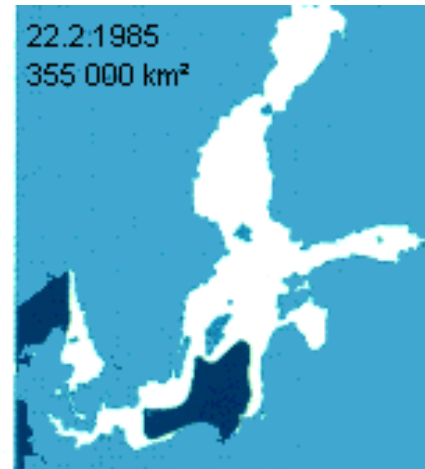
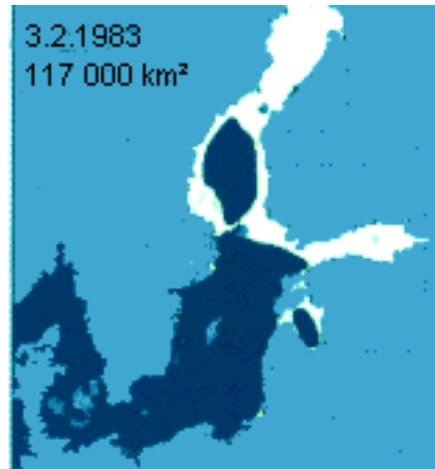
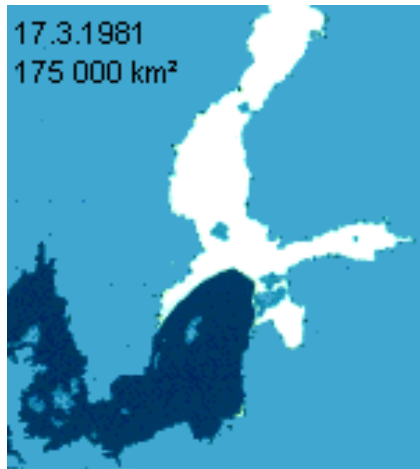
# Ice conditions in the Baltic Sea

Probability of  
freezing



Kuva 7.1. Jäätymisen vuotuinen todennäköisyys Itämerellä. (SMHI ja Merentutkimuslaitos 1982)

# Baltic ice winter



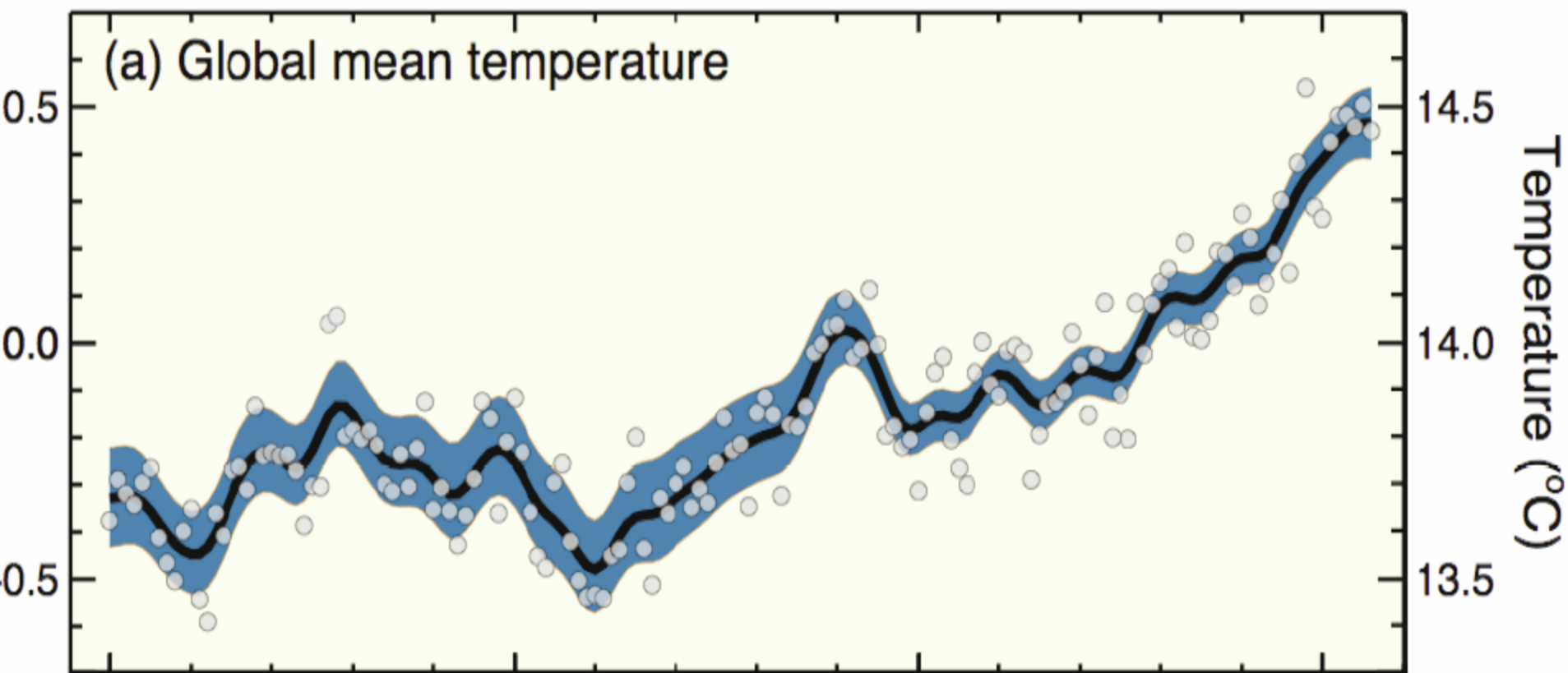


# Can the Climate Change be detected in the Baltic Sea?





# MAAPALLON KESKILÄMPÖTILA, 1850-2006



# How the Climate Change is now recognized in the BS?

- The sea-surface **temperature** has increased 0.5-0.8 degrees in 50 years,
- The surface **salinity** has decreased by 0.2 per milles (mean salinity 7 per milles)
- Mild or normal ice winters since 1987 until 2010
- New sea-level maxima (increasing frequency of high winds)



# What will happen in the Future until 2100?

Precipitation: Decreases in summer (even 45%), increases in winter (even 25-75%)

River runoff decreases in summer, increases in winter even up to 50 % ⇒

**BS will NOT be a lake, salinity stratification will remain**

**Winter floodings will prevent major BS inflows?**

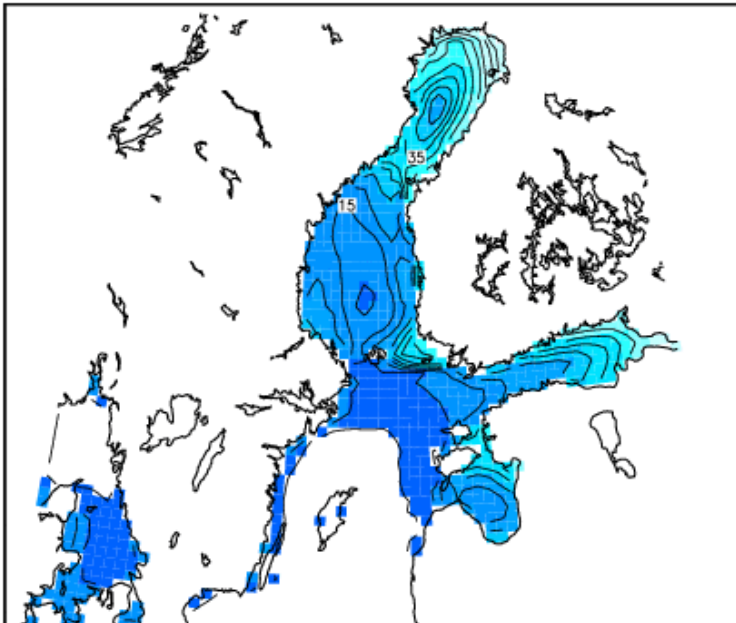




# Qualitative changes in ice conditions (J. Haapala)

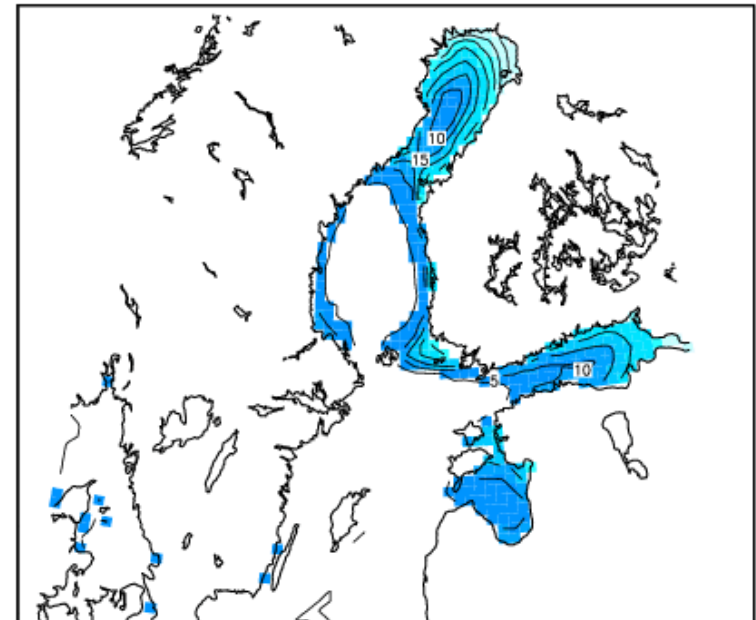
Pre-industrial time

Mean level ice thickness : 1 – 10 March



Year 2100

Mean level ice thickness : 1 – 10 March



**Q : Is there ice in the BS in 2100?**

**A :** Yes, but much less than at present. In the future only the easternmost Gulf of Finland the northernmost Bay of Bothnia will be ice-covered during **mild winters**.

# Oil accident

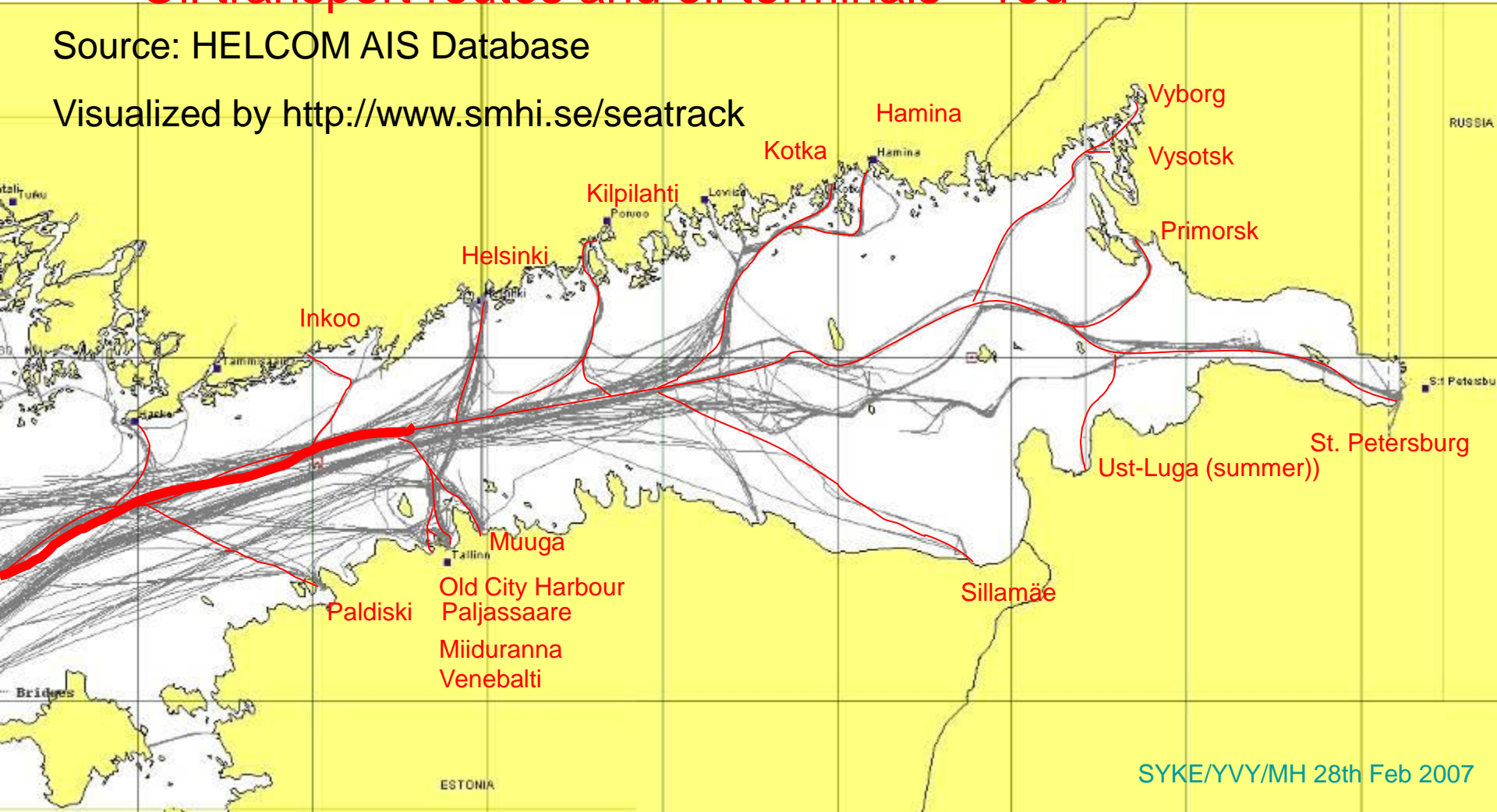


Traffic in the GOF during ole typical Wednesday (28th of Feb 2007)  
in ice conditions

## Oil transport routes and oil terminals – red

Source: HELCOM AIS Database

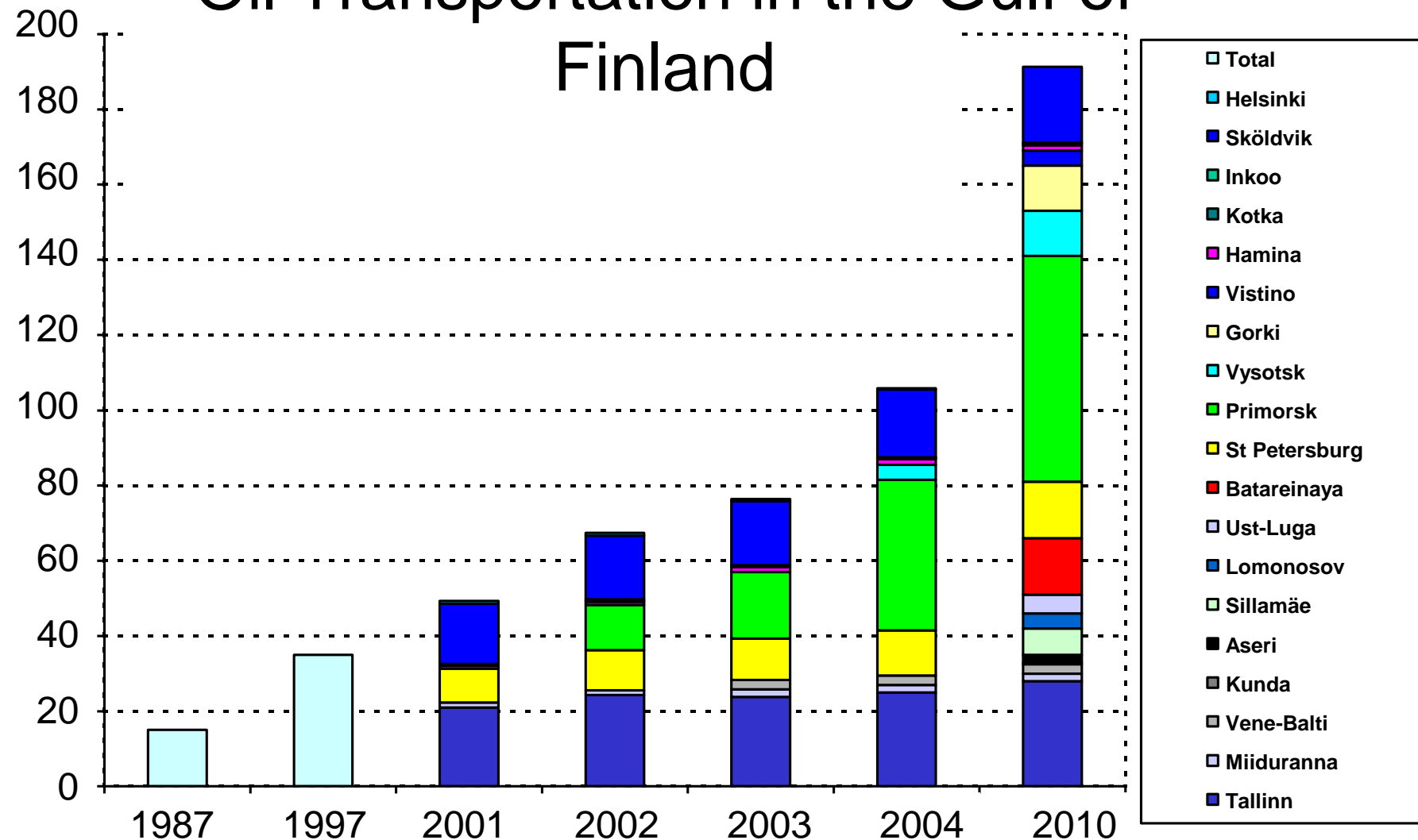
Visualized by <http://www.smhi.se/seatrack>



SYKE/YVY/MH 28th Feb 2007

In statistic Tallinn = Old City Harbour + Paljassaare + Paldiski + Muuga

# Oil Transportation in the Gulf of Finland





# New oil rescue vessel in the Gulf of Finland— but when?



7.9.2011

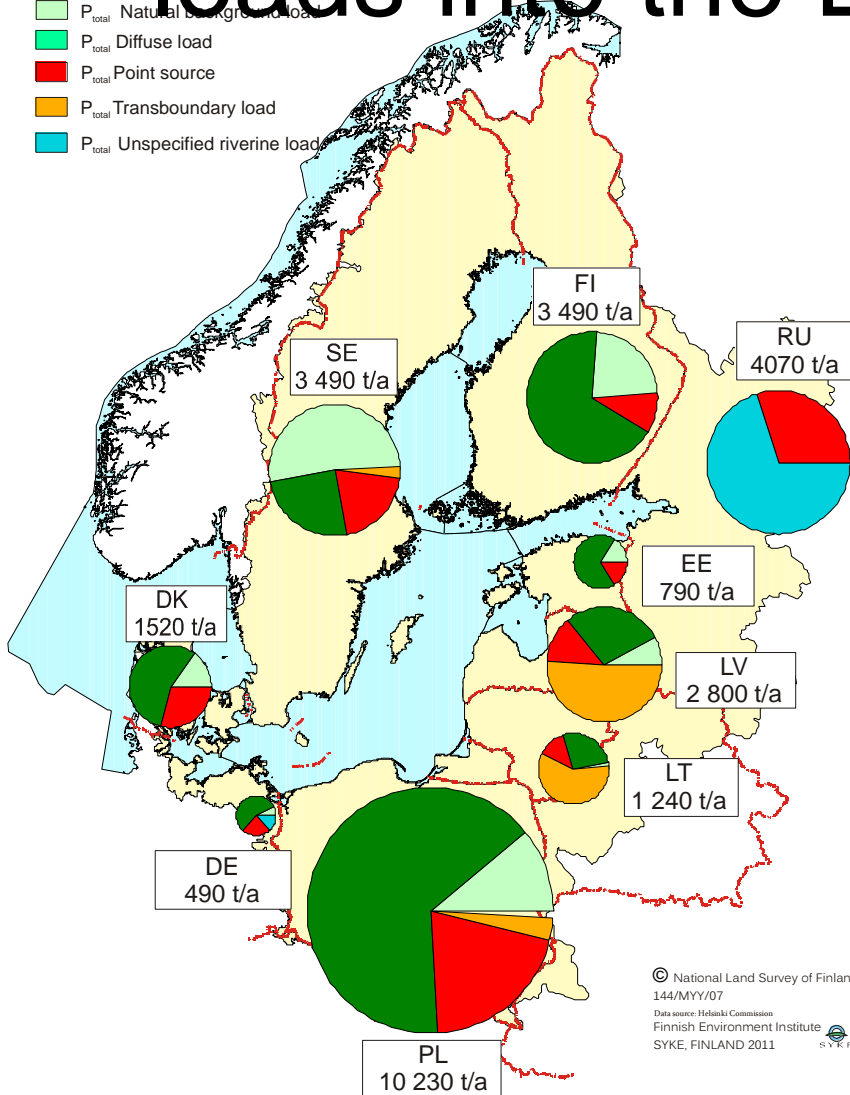


# The state of the Baltic Sea

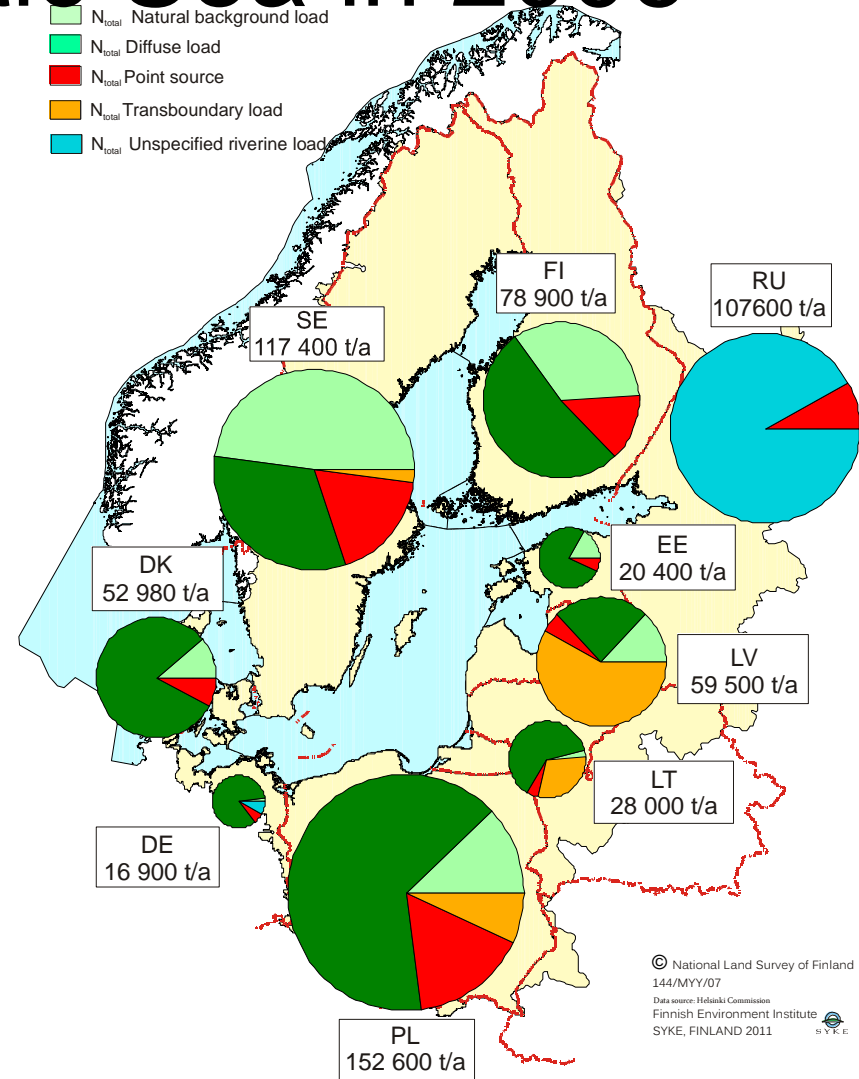


# Total phosphorus and nitrogen loads into the Baltic Sea in 2006

- P<sub>total</sub> Natural background load
- P<sub>total</sub> Diffuse load
- P<sub>total</sub> Point source
- P<sub>total</sub> Transboundary load
- P<sub>total</sub> Unspecified riverine load



- N<sub>total</sub> Natural background load
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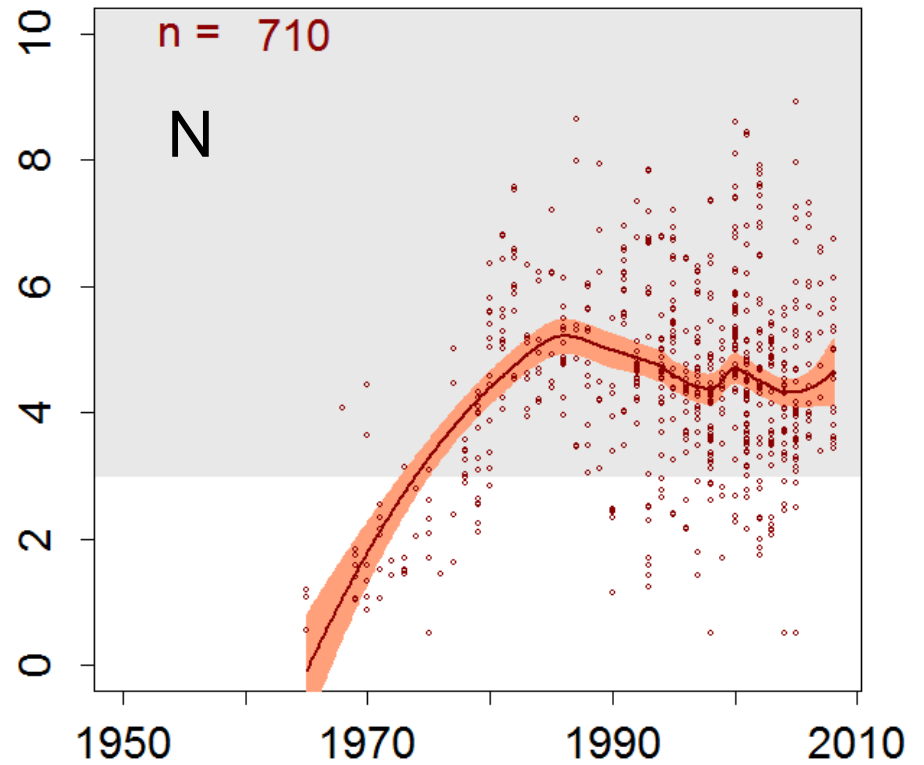
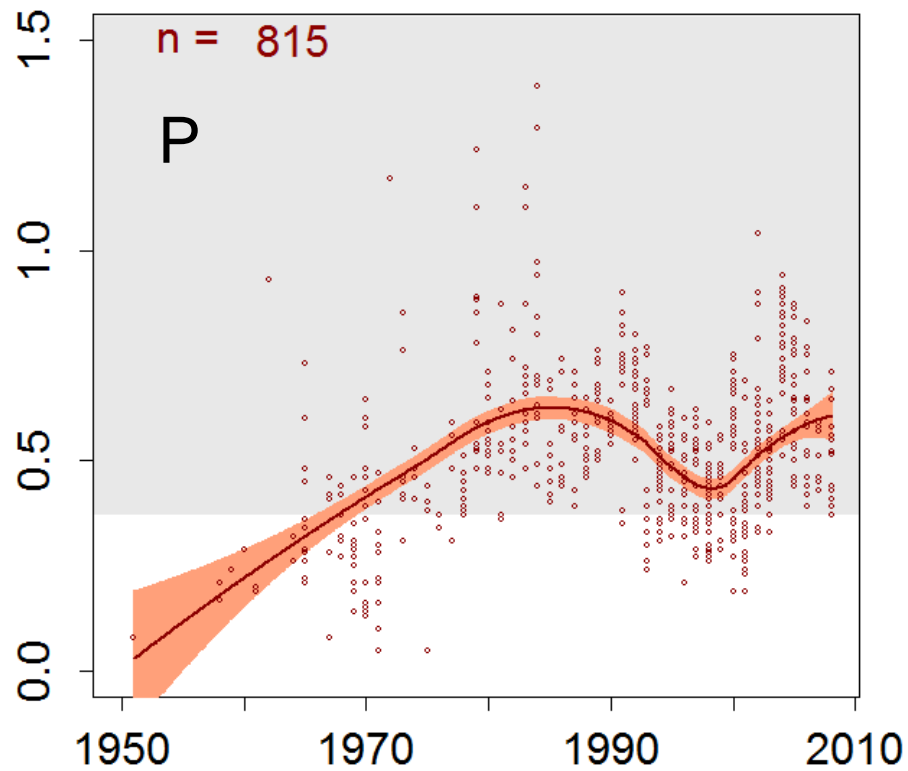


© National Land Survey of Finland  
144/MYY/07  
Data source: Helsinki Commission  
Finnish Environment Institute  
SYKE, FINLAND 2011

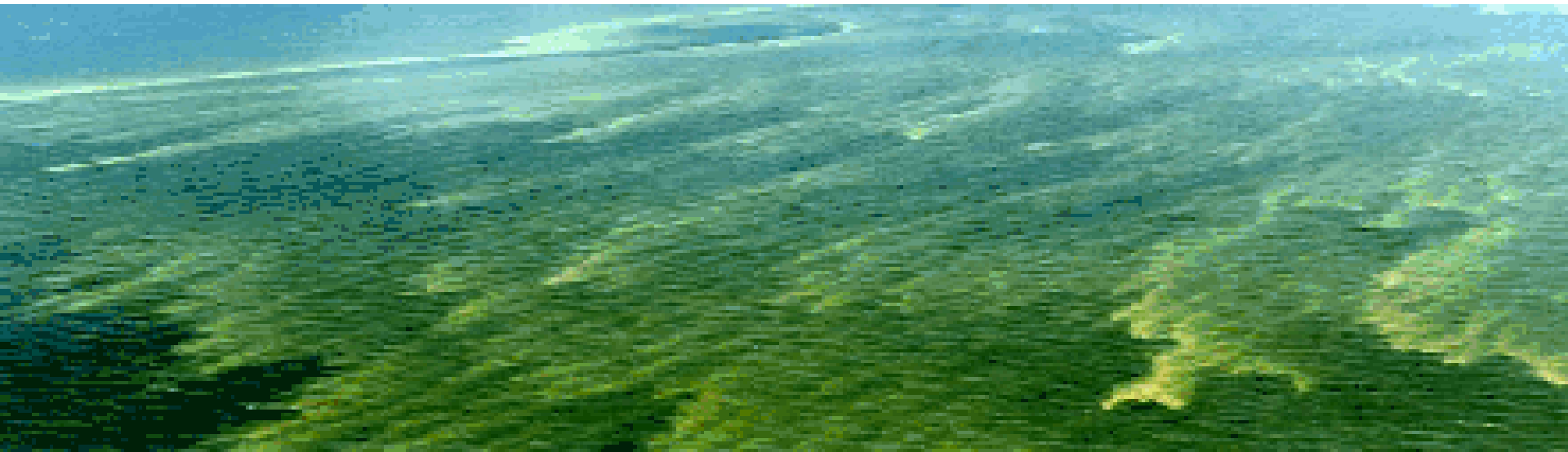
© National Land Survey of Finland  
144/MYY/07  
Data source: Helsinki Commission  
Finnish Environment Institute  
SYKE, FINLAND 2011



# Phosphorus and nitrogen concentrations in northern Baltic Proper

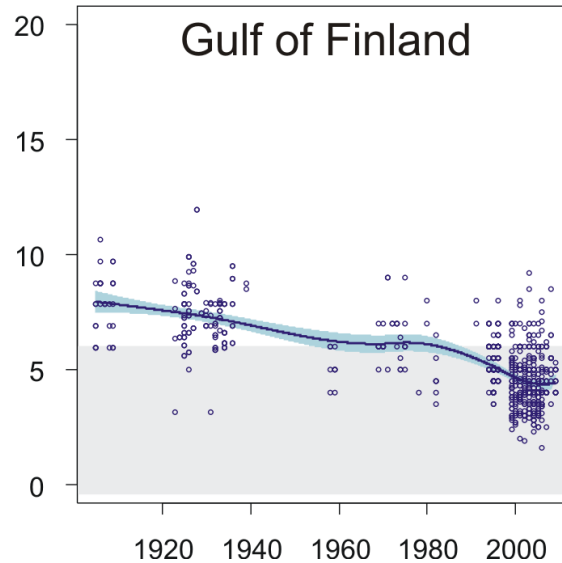
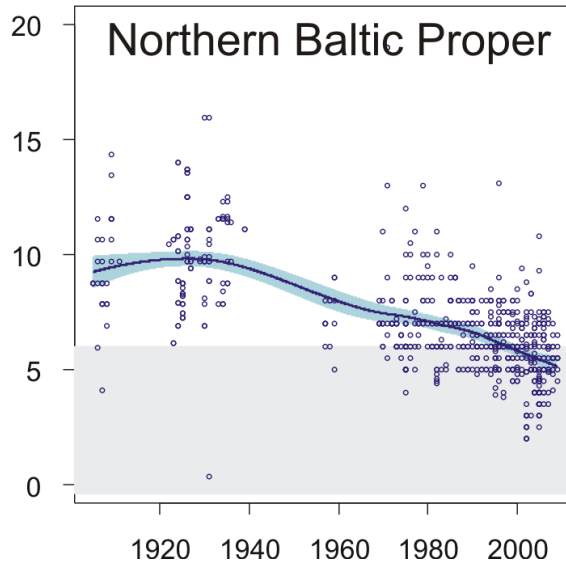
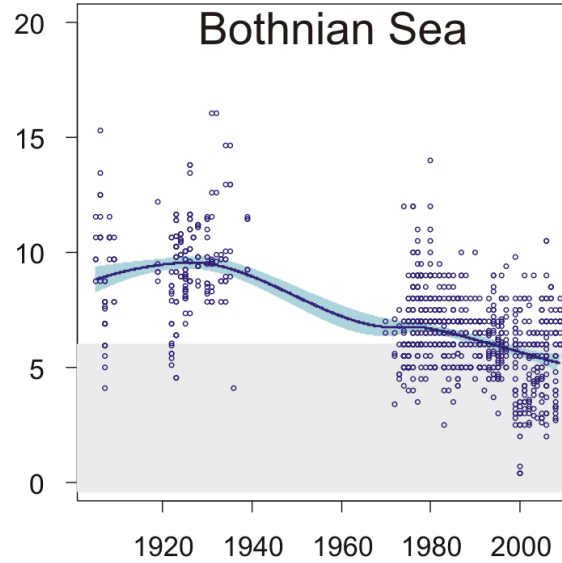
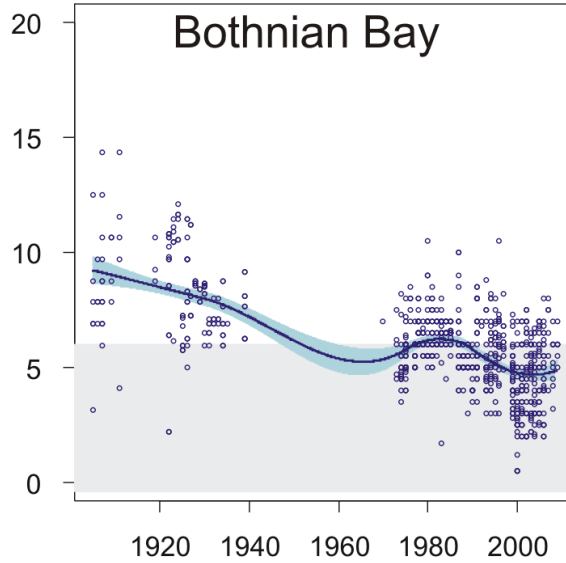


# Algae blooms

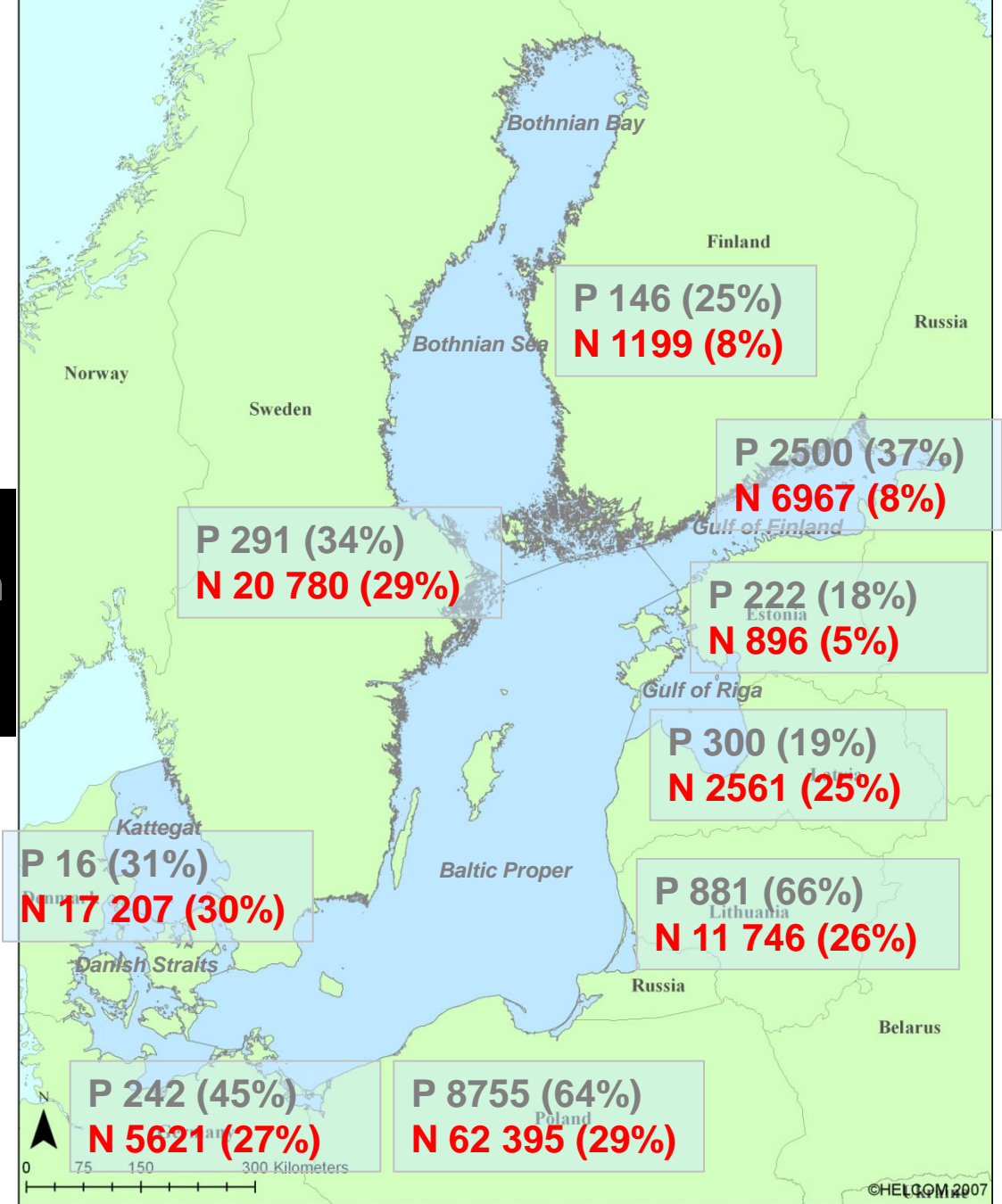


# State of the BS

- Secchi--depth (Fleming-Lehtinen)



Load reduction recommendation per country (tons/Year)



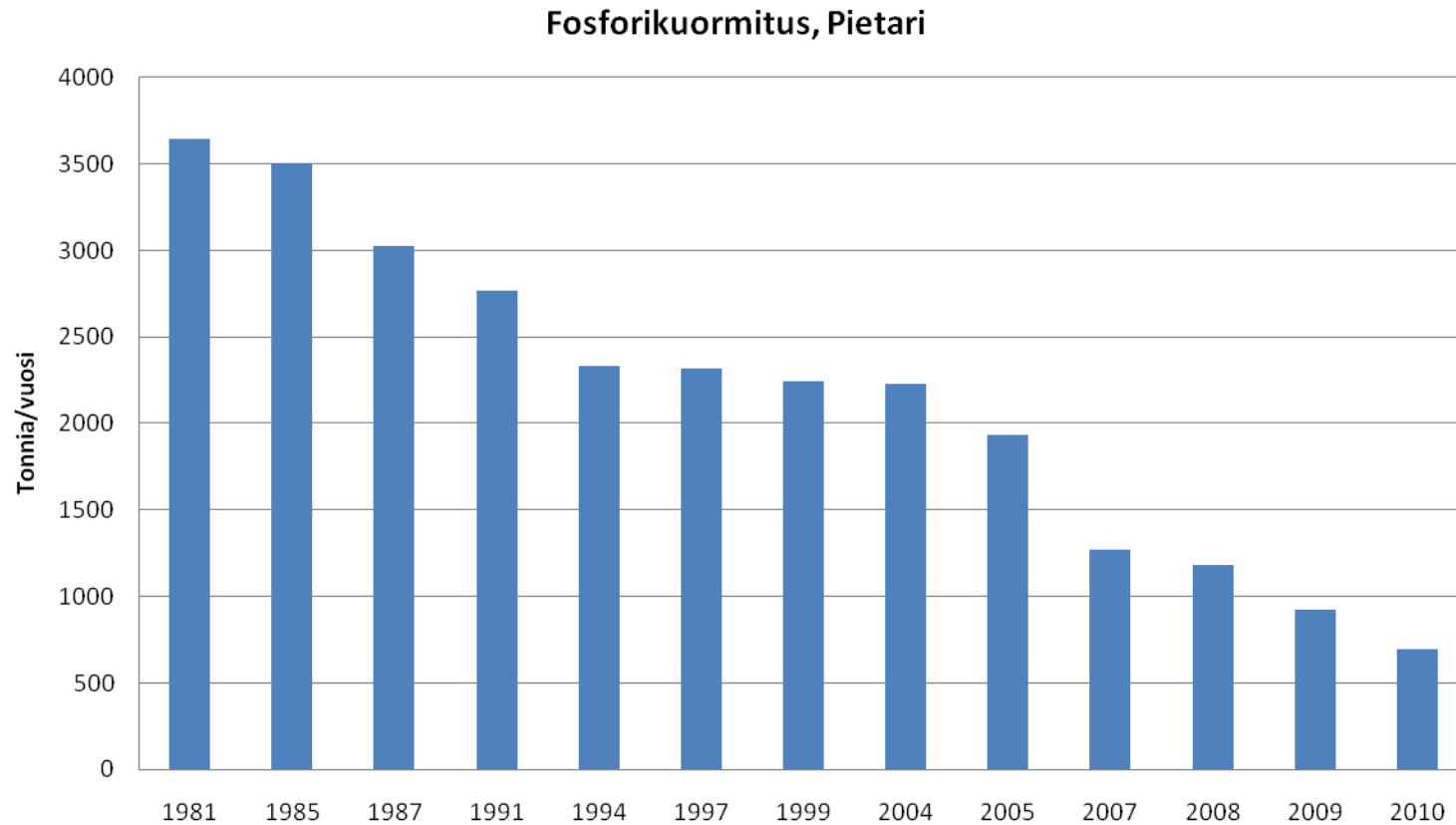


# Nutrient loads in St.Petersburg by Vodokanal

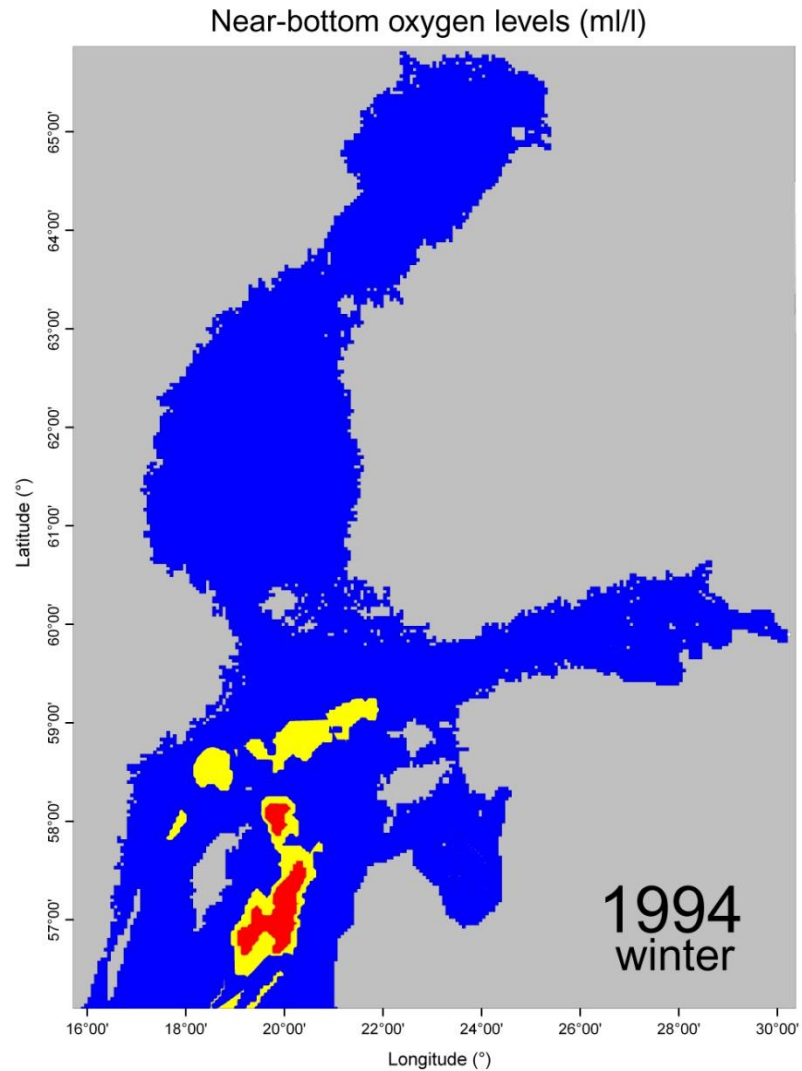


Photo: The John Nurminen Foundation

# Phosphorus load from St.Petersburg (tons/year)

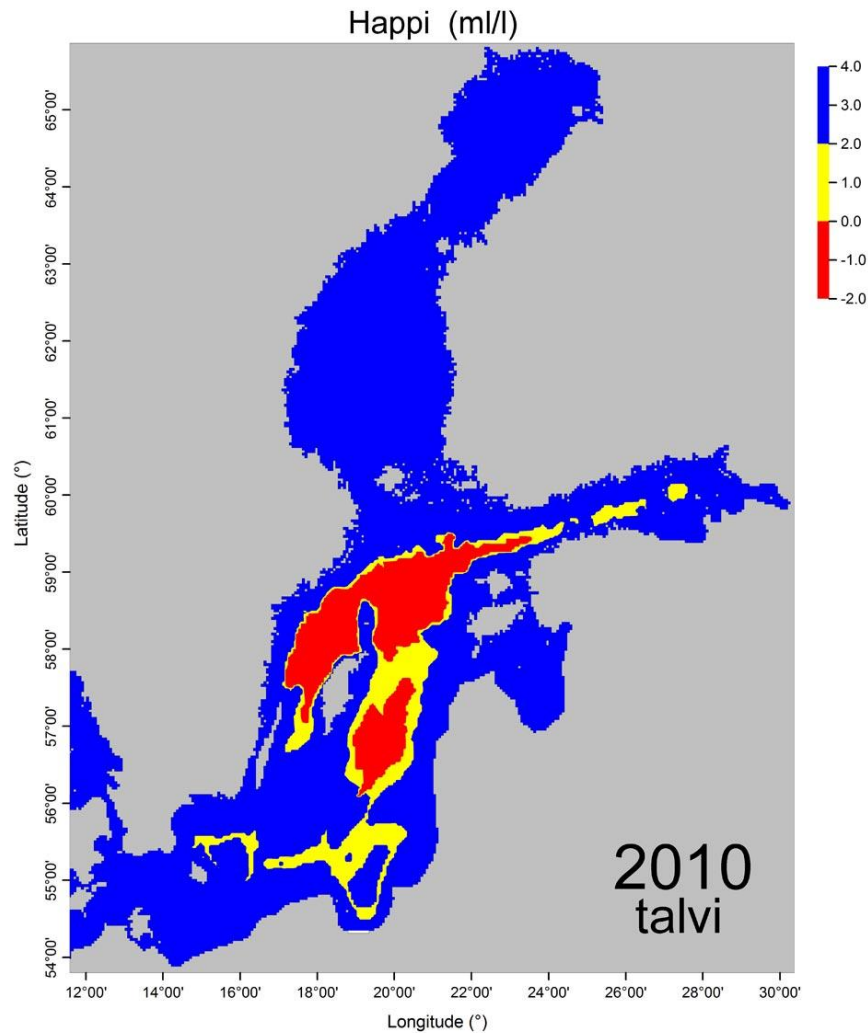


# Near-bottom oxygen conditions in winter 1994





# Near-bottom oxygen conditions in winter 2010





# This is the Baltic Sea Future— No Thanks!



# Baltic Sea Future

- The worsening of the State of the valuable BS is a big problem for our society → a binding protection agreement is needed, good administration is required
- The inheritance of socialism makes the protection very complicated
- Loadings and risks of marine transport should be taken care off
- Climate Change requires quick response
- Activity of the Citizens should be supported



S Y K E



**Thanks,  
*for your  
Attention***

